



DEVELOPMENT AND PERFORMANCE EVALUATION OF AN ARDUINO-BASED DLP RESIN 3D PRINTER

Anushka Chavan, Sunil Pal, Ashkaan Shaikh, Neha Singh, Sitaram Longani

Department Of Electronics And Telecommunication Engineering,
ISB&M College Nande, Pune, India

Abstract: This paper presents the design, development, and performance evaluation of an **Arduino-based Digital Light Processing (DLP) resin 3D printer**, focusing on creating an affordable, open-source alternative to commercial resin printers. The system utilizes an **Arduino Nano microcontroller** to control a combination of **UV LEDs** and an **LCD masking screen**, enabling precise photopolymer resin curing. Key features include custom firmware for stepper motor control, optimized UV exposure techniques, and cost-effective hardware integration. Results from cutting edge experiments clearly show printers of unmatched quality and superior usefulness of materials with big cost savings that are huge. The study brings things to a close highlighting some really cool ways this thing could be put to use and proposing some awesome ways to mix things up and make that thing even better.

Keywords - Arduino Nano, Digital Light Processing (DLP), Resin 3D Printer, UV Curing, Open-Source Hardware, LCD Masking Technology, Stepper Motor Control.

1. Introduction

The emergence of **3D printing technologies** has transformed traditional manufacturing processes, offering new possibilities in **prototyping, medical applications, education, and industrial design**. There are all sorts of cool technologies called 3D printing that have really caught on lately. One of them is called DLP which is really fantastic because it's great at making super detailed things with super smooth surfaces showing off beautiful resolution. It's popping up everywhere and everyone's excited because of the clarity and compact texture that results from its particular technique.

Unlike **Fused Deposition Modeling (FDM)**, which builds objects layer-by-layer through melted filament extrusion, **DLP technology** employs a light source to cure liquid resin selectively. This process lets us work much faster and include finer details too. The big expense on fancy resin 3D printers can be a stumbling block to entry for people who just want to design and make cool things in small batches or who are in research and start-ups who want to customize prototypes before moving onto bigger stuff.

1. 1 Objectives of the Study

Develop an affordable printer using readily available components.

To Promote Open-Source Hardware Development: Enable replication and modification by DIY enthusiasts.

To Achieve High-Resolution Printing: Optimize UV exposure and motion control systems for precise curing.

To Enhance Educational Applications: Provide a practical project for learning about embedded systems, 3D printing, and electronics.

1. 2 Problem Statement

The main challenge addressed in this paper is the **prohibitive cost** and **complexity** of commercial resin 3D printers. Many require **specialized hardware** and **proprietary software**, limiting accessibility. This project proposes a solution by creating an **Arduino-based, open-source DLP resin printer** with comparable performance at a fraction of the cost.

2. Literature Review

2. 1 Overview of DLP 3D Printing Technology

Digital Light Processing (DLP), first introduced by Texas Instruments, uses a **digital micromirror device (DMD)** to control light projection. In DLP 3D printing, a **UV light source** passes through an **LCD mask** to selectively cure layers of **photopolymer resin**. This technique offers:

- **High-Speed Printing:** Entire layers are cured simultaneously.
- **Precision:** Capable of achieving resolutions as fine as 25 microns.
- **Smooth Surface Finish:** Ideal for applications requiring detailed aesthetics, such as jewelry or dental models.

2. 2 Arduino's Role in Additive Manufacturing

The Arduino platform has revolutionized embedded systems due to its simplicity, low cost, and vast open-source community. In 3D printing:

- **Motion Control:** Manages stepper motors for precise axis movement.
- **Sensor Integration:** Monitors limit switches, temperature, and environmental conditions.
- **Real-Time Processing:** Controls UV LED exposure with microsecond precision.

2. 3 Challenges in DLP Printing

- **Heat Management:** UV LEDs generate significant heat, affecting print quality.
- **Exposure Calibration:** Incorrect UV exposure times can lead to over-curing or under-curing.
- **Mechanical Stability:** Z-axis wobble affects print consistency.
- **Material Handling:** Resin properties vary, requiring precise control of curing conditions.

3. System Design and Architecture

3.1 System Architecture

The printers we're putting forward have three core systems that make them really special.

- **Mechanical Subsystem:** Controls vertical movement of the build platform using a stepper motor and lead screw mechanism.
- **Optical Subsystem:** Uses UV LEDs and an LCD screen to shine light that turns photosensitive resin into strong hard shell stuff.
- **Control Subsystem:** Operated via an Arduino Nano, responsible for managing motor movements, exposure timing, and system diagnostics.

3.2 Hardware Specifications

Component	Specification	Function
Arduino Nano	ATmega328P Microcontroller	Central processing and control unit
UV LEDs	405 nm Wavelength, High Intensity	Resin curing through photopolymerization
LCD Screen	1280 × 800 Resolution	Acts as a dynamic mask for UV light
NEMA 17 Stepper Motor	1.8° Step Angle, 42 N·cm Torque	Controls precise Z-axis movement
Lead Screw (T8)	2 mm Pitch	Converts rotational motion to linear motion
Limit Switches	Mechanical Endstops	Prevents overtravel of the build plate
Power Supply	12V, 5A	Provides stable power to all components

3.3 Software Architecture

- **Firmware:** Written in C++ using the Arduino IDE.
- **Motion Control:** Uses the **GRBL** library for stepper motor management.
- **Slicing Software:** **ChiTuBox** processes 3D models (STL format) into 2D image layers (BMP format).
- **Communication Protocol:** Python-based scripts send G-code commands from the host computer to the Arduino for print execution.

4. Methodology

4.1 Working Principle

1. **Model Preparation:** The 3D model is sliced into layers using slicing software.
2. **Data Transmission:** Each sliced image is sent to the LCD screen.
3. **Resin Curing:** UV light passes through the LCD mask to refine the resin selectively.
4. **Platform Adjustment:** After each layer is refined, the stepper motor lowers the build platform.
5. **Post-Processing:** The printed object is cleaned with isopropyl alcohol and post-cured under UV light.

5. Implementation

5.1 Circuit Design

The system includes:

- **Arduino Nano:** helps with motor drivers and UV control circuits.
- **Motor Driver (A4988):** Provides current regulation and moto controls for smooth motion.
- **MOSFET Switches:** Handle high-power switching for UV LEDs.
- **Endstop Switches:** Ensure accurate positioning for the Z-axis.

5.2 Firmware Development

- **Programming Language:** C++ (Arduino IDE)
- **Functions:**
 - i. **Real-time Motion Control:** Ensures smooth platform movement.
 - ii. **UV Exposure Timing:** Manages refining duration with millisecond accuracy.
 - iii. **Error Handling:** Detects system faults and prevents hardware damage.

6. Results, Conclusion and Discussion

6.1 Conclusion

This research successfully demonstrates the development of an **Arduino-based DLP resin 3D printer** that is **cost-effective, accessible, and capable of producing high-quality prints**. The project provides a foundation for future exploration in open-source 3D printing technologies.

6.2 Performance Metrics

Parameter	Measured Value	Commercial Benchmark
Layer Thickness	50 microns	25–100 microns
Print Speed	4–6 seconds per layer	2–5 seconds per layer
Build Volume	120 × 68 × 150 mm	115 × 65 × 155 mm
Surface Finish	Smooth with minimal lines	Comparable to SLA printers

6.3 Observations

- **Print Quality:** High-resolution details with smooth finishes.
- **Reliability:** Consistent layer adhesion and structural integrity.
- **Cost Efficiency:** Total build cost between Rs. 5000 to Rs. 10,000, significantly lower than commercial DLP printers.

6.4 Challenges and Solutions

Challenge	Solution Implemented
Inconsistent Layer Adhesion	Optimized exposure times and improved resin mixing.
Heat Accumulation in LEDs	Integrated active cooling systems.
Z-Axis Stability Issues	Added anti-backlash nuts for precise motion.
Firmware Glitches	Implemented robust error-handling protocols.

6.5 Future Scope

- **Wireless Connectivity:** Incorporate Bluetooth/Wi-Fi for remote monitoring.
- **Auto-Leveling Mechanisms:** Improve platform stability.
- **Advanced Resin Materials:** Explore flexible and biocompatible resins for specialized applications.

7. References

1. Hull, C. W. (1986). *Apparatus for Production of Three-Dimensional Objects by Stereolithography*. US Patent.
2. Arduino. (2024). *Arduino Nano Technical Specifications*. [Online] Available: www.arduino.cc
3. ChiTuBox. (2023). *Resin 3D Slicing Software Documentation*.
4. GRBL Firmware. (2024). *Open-Source CNC Motion Control*. GitHub Repository.
5. Luna, M. M. (2024). *Arduino DLP Printer – Project Documentation*.
6. Gao, W., Zhang, Y., & Ramani, K. (2015). "Digital Light Processing (DLP) 3D Printing for Rapid Manufacturing: Review and Future Directions." *Journal of Manufacturing Science and Engineering*, 137(3), 034001.
7. Petrakis, E., et al. (2021). "Development of an Affordable Open-Source DLP 3D Printer for Biomedical Applications." *Journal of Biomedical Materials Research*, 109(6), 1124-1135.
8. Reina, G., & Pardo, M. (2020). "Low-Cost Resin 3D Printer Using DLP Technology for Rapid Prototyping." *IEEE Access*, 8, 152300-152314.
9. GRBL Firmware. (2024). *Open-Source CNC Motion Control*. GitHub Repository.