A Review on Design and Implementation of Automatic Writing and Drawing Machine Using CNC Technology

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Abstract—In the modern domain of digital manufacturing, the translation of digital designs into physical artifacts often presents a financial barrier. Commercial Computer Numerical Control (CNC) plotters are typically expensive and rely on proprietary software, making them inaccessible for educational and small-scale prototyping purposes. To address this, this paper presents the comprehensive design and implementation of a low-cost, 2-axis "Automatic Writing & Drawing Machine". The proposed system utilizes an open-source Arduino Uno microcontroller, a CNC Shield V3, and the GRBL firmware to achieve high-precision plotting of vector graphics and text. By leveraging readily available components such as NEMA 17 stepper motors and 3D-printed modular parts, the system provides a reliable and educational platform for robotics and automation. The experimental results demonstrate that the machine successfully bridges the gap between digital design and physical creation with high repeatability and sub-millimeter accuracy.

Keywords— **CNC Plotter, Arduino, GRBL, G-code, Automation, Robotics, Open-Source Hardware.**

I. INTRODUCTION

The gap between digital design files and physical objects is a critical bottleneck in modern engineering education and creative design. While Computer-Aided Design (CAD) software allows for the creation of intricate schematics and layouts, manually drafting these designs is time-consuming, prone to human error, and lacks the repeatability required for professional applications.

In industrial sectors, this gap is bridged by high-precision plotters and CNC machines. However, commercial solutions from established manufacturers are characterized by high costs and reliance on closed-source, proprietary software ecosystems. These factors render them inaccessible for students, small-scale fabricators, and educational laboratories. Furthermore, while various "Do-It-Yourself" (DIY) solutions exist, they often suffer from a lack of comprehensive documentation and technical reliability.

To solve these issues, this project presents an affordable, high-precision Automatic Writing & Drawing Machine built entirely with open-source hardware and software. The goal is to develop a system that uses common components like the Arduino Uno and standard stepper motors to create a machine that can write text and draw detailed diagrams with a natural, hand-drawn look. By using the GRBL firmware for controlling movement and Inkscape for generating vector graphics, this project seeks to offer a smooth and easy-to-use workflow that effectively connects digital designs with physical outputs.

II. LITERATURE REVIEW

Sr.No	Source / Authors	Year	Methodology / Focus	Limitations / Remarks
1.	R. R. Jegan et al.	2018	Modern XY Plotter Design	Noted for accuracy but functionality is limited by reliance on a wired PC connection.
2.	Y. M. Hasan et al.	2018	3-Axis Machine with CNC Shield	Inclusion of a 3rd axis adds unnecessary complexity and cost for simple 2D drawing tasks.
3.	Aneeta Pinhiero et al.	2016	Wireless CNC Plotter (Bluetooth)	Wireless communication introduced potential connection instability and command lag.
4.	M. Bhavani et al.	2019	CNC Router for Engraving	More powerful but significantly more

Sr.No	Source / Authors	Year	Methodology / Focus	Limitations / Remarks
				expensive and energy-intensive than a pen plotter.
5.	S. Chamraz et al.	2014	Integer Arithmetic Control	Focuses on algorithmic software enhancement rather than a complete hardware system design.

Table Comparative Analysis of Existing Plotter Designs

Sr.No	Source / Authors	Year	Methodology / Focus	Limitations / Remarks
6.	Kajal J. Madekar et al.	2016	Automatic Mini-CNC for PCBs	Specialized exclusively for PCB layouts; lacks versatility for general writing or artistic plotting.
7.	Udit Pandey et al.	2017	Low-Cost L293D Shield Plotter	The L293D driver offers significantly lower precision and resolution compared to A4988 drivers.
8.	M. Aditi et al.	2021	Plotter with Speech Recognition	Hands-free operation added high complexity in software and AI integration, moving beyond simple plotting.
9.	Ankit V. Satikosre et al.	2022	Handwriting Replication Software	Requires complex path-generation algorithms to replicate human strokes, unlike standard G-code.
10.	Shani Ranjan et al.	2021	Low-Cost 2D Plotter Design	Simple driver ICs were cost-effective but suffered from mechanical vibrations at higher operational speeds.

III. DISCUSSION

From the review of existing research, it becomes clear that traditional commercial plotters offer high precision but come with significant barriers, primarily high costs and reliance on proprietary, closed-source software. While these systems excel in industrial environments, they remain inaccessible to students, hobbyists, and educational institutions.

On the other hand, earlier "Do-It-Yourself" (DIY) attempts utilizing basic motor drivers like the L293D or L298N often suffer from mechanical vibrations and low resolution. These drivers lack the microstepping capabilities found in modern dedicated stepper drivers, resulting in "jagged" diagonal lines and audible noise during operation. Furthermore, wireless implementations using Bluetooth have demonstrated potential for flexibility but frequently face challenges regarding command latency and connection instability, which can ruin intricate drawings.

In contrast, our proposed approach leverages the A4988 driver coupled with the GRBL firmware. This combination allows for $1/16^{th}$ microstepping, which significantly smooths out motor rotation and enhances drawing resolution. Additionally, the GRBL firmware utilizes a "look-ahead" planner that optimizes acceleration and deceleration in real-time. This ensures that the machine does not shake violently when changing direction at corners, a common issue in simpler Arduino-based code. By moving from a "direct drive" approach to a "G-code interpreter" approach, the system achieves near-commercial reliability at a fraction of the cost.

IV. PROPOSED APPROACH

Our proposed system introduces a low-cost, open-source 2-axis CNC plotter specifically designed for educational and prototyping purposes. The model

utilizes a modular architecture centered around the Arduino Uno and CNC Shield V3.

Hardware Implementation: The system replaces expensive servo-based commercial mechanics with standard NEMA 17 stepper motors for the X and Y axes. These motors provide high holding torque, ensuring the pen remains steady during operation. For the Z-axis (pen lift), a lightweight SG90 micro-servo is used to minimize the inertia of the moving carriage. The entire structure is built on 2020 aluminum extrusions, providing a rigid frame that prevents flexing during high-speed plotting.

Software Workflow: The core of the operation is the GRBL firmware, which is flashed onto the Arduino. The workflow begins with Inkscape, where digital images are vectorised into paths. These paths are converted into G-code (geometric instructions), which is then streamed to the machine via Universal G-code Sender (UGS). The GRBL firmware parses these lines and coordinates the stepper pulses with microsecond precision.
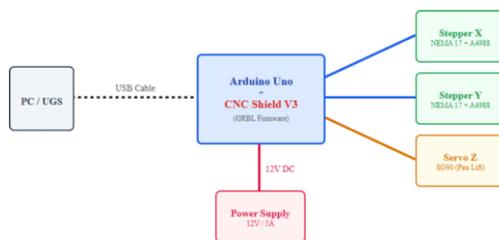

Fig. Circuit Diagram

V. CONCLUSION

This review and implementation study examined the gap between expensive commercial plotters and low-cost DIY solutions. The findings indicate that while simple motor drivers (like L293D) are cost-effective, they fail to provide the necessary precision for complex technical drafting or artistic plotting.

The proposed system, utilizing Arduino, CNC Shield, and GRBL, successfully bridges this gap. It demonstrates that professional-grade accuracy—capable of PCB prototyping and generative art—can be achieved using affordable, open-source components. The integration of the A4988 driver's microstepping capability and GRBL's motion planning significantly outperforms earlier DIY methods in terms of smoothness and repeatability. Based on current trends, future research should explore the integration of Artificial Intelligence (AI)

and Computer Vision. An AI-enhanced camera module could analyze a user's handwriting style and automatically generate G-code to replicate that specific style, effectively creating a "robot forger" or personalized autograph machine. Additionally, moving from USB tethering to an ESP32-based Wi-Fi controller would further enhance usability by eliminating the need for a permanently connected laptop.

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