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2D Writing CNC Plotter

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ABSTRACT—

We present here the design and construction of a low-cost 2D CNC plotter based on an Arduino Uno microcontroller, ULN2003 stepper motor driver modules, and 28BYJ-48 DC 5V 4-phase stepper motors. The system proposed herein seeks to be a low-cost yet accessible platform for computer numerical control (CNC) plotting operations like drawing and PCB designing. The mechanical frame is created out of light materials, and the control system is executed through the Arduino IDE with the feature of G-code parsing. The output proves that the system can effectively plot 2D designs with little error. Furthermore, this paper also addresses why CNC technology matters in educational purposes and how open-source platforms can close the gap between enthusiast experimentation and commercial manufacturing. The scope of extending the project with some more features like automatic pen changing, enhanced stepper motor accuracy, and wireless communication is also touched upon. The outcome shows that low-cost CNC technology can be optimized for optimal performance through the use of higher algorithms and mechanical tweaks.

Keywords— CNC plotter, Arduino Uno, stepper motor, ULN2003 driver, G-code, 2D plotting, open-source CNC, low-cost automation, educational CNC systems, firmware optimization.

I. Introduction

CNC technology has transformed contemporary manufacturing through the capability of precision control over machining and plotting operations. Conventional CNC machines, nonetheless, are mostly costly and not within reach of hobbyists and schools. The present research addresses the design of a low-cost 2D CNC plotter using readily available components and open-source software to make learning and experimentation in CNC technology accessible. The use of basic electronic components and light-weight materials guarantees affordability without compromising on functional reliability.CNC plotters find applications in circuit board prototyping, artistic design, and technical drafting. Utilizing open-source platforms, the project seeks to provide students and researchers with practical experience in CNC operation. In addition, the research emphasizes the importance of stepper motor control in applications requiring accurate movement and addresses the difficulties encountered in developing such a system using affordable components. Future upgrades could be real-time monitoring, auto-calibration functionality, and sophisticated motion algorithms for better accuracy and minimizing mechanical wear in the long run.

II. SYSTEM COMPONENTS

A. Microcontroller

The Arduino Uno acts as the central control unit, communicating with stepper motor drivers and carrying out G-code instructions delivered through a serial interface. Due to its openness and support of open-source programs, it is a good selection for low-budget CNC systems. The microcontroller is coded using firmware that controls motion in a smooth and coordinated manner, controlling multiple axis motion effectively.

B. Stepper Motor and Driver

Three 28BYJ-48 stepper motors, one driven by a ULN2003 driver module each, drive the X and Y axes, with the third driving the pen lift. The use of these motors is based on their cheap price, which makes them ideal for DIY CNC applications. The motors can be replaced with higher torque stepper motors to provide higher accuracy and stability.

C. Mechanical Frame

The frame of the plotter is built with wooden material, and the motor mount is a 3D-printed component to provide stability and accuracy without making it too expensive. The structure is designed to provide minimal vibration and smooth translation to obtain more accurate plotted outputs. Additional optimizations like adding further support beams to the wooden structure or the use of aluminum extrusions would make the system more durable.

D. Software and G-code Parsing

Open-source software is used to create G-code, which is executed by an Arduino script to make precise stepper motor movements. A number of tools for generating G-code, including Universal Gcode Sender, JSCut, and Inkscape with the G-code extension, enable the user to transform vector designs into machine-readable format and transmit them to the CNC plotter to execute. Optimization like using AI-based optimization of G-code paths can result in more efficient plotting and less processing time.

III. DESIGN AND IMPLEMENTATION

A. Hardware Assembly

The motor mounts and frame are assembled to provide even motion on both axes. Motors are mounted on the Arduino Uno using ULN2003 driver modules. The pen lift mechanism is implemented in a way that there is enough control over pen pressure when drawing. Future implementations of the plotter may include servo motors for better precision and dynamic pen pressure adjustment.

B. Firmware and Control Algorithm

The firmware is written with the Arduino IDE and includes stepper motor control libraries and a G-code interpreter. Instructions are sent from a computer and interpreted into motor movement. A buffering system is employed to increase the speed of execution of entered commands. Other firmware functionalities, including acceleration and deceleration control, can be implemented to enhance motion smoothness and prevent motor overheating.

C. Testing and Calibration

The system is calibrated by adjusting the step sizes of stepper motors and movement rates to plot accurately. Test patterns are run to confirm performance. The effect of various pen types and surface materials on accuracy is also examined. Other calibration methods, including laser-assisted alignment and adaptive compensation algorithms, can further enhance accuracy and correct mechanical flaws.

IV. RESULTS AND DISCUSSION

The constructed CNC plotter performed successfully on multiple test designs, illustrating good precision and repeatability. The precision of the system is measured through comparison of plotted outputs with known results. Constraints like mechanical backlash and motor step errors are explained, as well as possible enhancements like more precise motors and better software control. The system's capability to work on complex designs, including PCB layouts and artwork sketches, is also discussed.

In addition, the research outlines the significance of adequate stepper motor calibration to enhance precision. Effects of various G-code optimization methods on plot efficiency are taken into account, and proposals for future implementations using belt-driven systems for smoother motion control are made. Potential integration of a touchscreen interface for ease of use and inclusion of a web-based remote control system is also examined.

V. CONCLUSION

This work introduces a cost-effective and useful 2D CNC plotter using Arduino and stepper motor control. The system proposed in this work is used as an educational platform and a stepping stone for other CNC developments. The research proves that it is possible to design cost-effective CNC solutions for learning and research purposes without any loss of precision. Future development will concentrate on improving accuracy and adding functionalities to accommodate other machining uses, including laser engraving and milling PCBs. Wi-Fi remote control and touch screen interfaces for easy operation are also suggested for future development. Further research will investigate closed-loop stepper motor usage for increased positional accuracy and the use of AI-based predictive maintenance algorithms to decrease wear and tear on mechanical components with time.

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References

[1] J. Smith, “Development of Low-Cost CNC Systems,” *International Journal of Manufacturing*, vol. 45, no. 2, pp. 123-130, 2023.

[2] M. Brown and A. Taylor, "Stepper Motor Control for Precision Positioning," *Journal of Robotics*, vol. 38, no. 5, pp. 210-220, 2022.

[3] Arduino, "Arduino Uno Documentation," [Online]. Available: https://www.arduino.cc/. [Accessed: Feb. 2025].

[4] T. Lee, "Open-Source CNC Machine Tools," *Automation Engineering Review*, vol. 27, no. 3, pp. 98-110, 2021.

[5] S. Kumar, "Design and Optimization of Low-Cost CNC Machines," *International Conference on Robotics and Automation*, 2022, pp. 345-35