International Journal on Science and Technology (IJSAT)

E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Arduino-Driven CNC 2D Sketcher for Rapid Architectural Plan Prototyping

Sandeep Yadav[1], Prem Kumar[2], Pravin Kumar[3]

School of Engineering,
[1,2]JB Institute of Technology, Dehradun, India
[3] IIEST Shibpur, Howrah, West Bengal, India
[1]sandeepyadav.sliet@gmail.com, [2]premhawal@gmail.com,
[3]Praviniiest@gmail.com

Abstract:

This paper presents the design and development of a low-cost, Arduino-based mini CNC plotter. The system utilizes stepper motors and guide rails repurposed from two DVD/CD-ROM drives to control the X and Y axes, offering a maximum working area of 5×5 cm. It operates through serial communication, making it compatible with various software platforms. With growing interest in affordable CNC systems, especially for educational and research purposes, this model addresses the need for budget-friendly tools in electronics and mechanical engineering labs. The plotter can be used for drawing circuit layouts on PCBs or other solid surfaces using simple, easily accessible components. Users first convert images or text into G-code using Inkscape, which is then sent to the machine via Processing software. An Arduino Uno interprets the G-code and controls the stepper motors via a motor driver, enabling accurate and automated plotting. This setup serves as a practical, compact solution for small-scale precision drawing applications.

Keywords: Computer Numerical Control; Printed Circuit Board (PCB); G-code; Arduino UNO.

1. Introduction:

The combination of Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) is essential for defining the tool path used by CNC (Computer Numerical Control) machines. This combination has significantly replaced conventional machining methods by offering enhanced flexibility, improved precision, and reduced production cycle times. In recent years, this integration has also been adopted in 3D printing technologies, which operate using G-code similar to that used in CNC machines. Developments in NC part programming and interactive computer graphics have contributed significantly to advancements in this field.

A recent investigation presented a cost-effective 3D CNC machine powered by an embedded system built on an 8-bit microcontroller, designed to fulfill industrial demands with precision and dependability. Additionally, another innovation involved an open-source CNC system that integrates a personal computer with a motion controller, incorporating two-order interpolation and Cubic B-spline curve segmentation for improved performance. Research has also explored automated tool change mechanisms to minimize tool change time and the use of grapheme nonmaterial coatings on CNC milling beds to enhance precision and durability. Currently, CNC machines and G-codes are being applied beyond traditional uses to include PCB drawing and drilling, EDM processes, material fabrication, and engraving. Several researchers have developed automatic mini CNC machines for PCB work and low-cost CNC plotters using salvaged components. This study focuses on the design and fabrication of a mini CNC 2D sketcher aimed at producing precise architectural drawings. The goal is to generate accurate building plans, elevations, and sectional views on A4 sheets using G-code instructions tailored to specific customer requirements, an area not yet explored extensively in prior work.

The Mini CNC plotter machine operates using an Arduino controller and a CNC shield. CNC stands for Computer Numerical Control, where G-codes play a key role as predefined commands that guide movements along the machine’s axes. In this plotter, only G-codes are used to direct the pen or tool along the X, Y, and Z axes. Although designed as a mini version, the system can be scaled up and adapted for additional tasks like drilling, laser cutting, or milling. The objective of this project is to build a compact CNC plotter capable of drawing complex designs on paper or metal surfaces with high precision. The setup includes three stepper motors with lead screws arranged in Cartesian X, Y, and Z directions. An Arduino Uno serves as the microcontroller that translates G-codes into machine instructions. Stepper drivers manage motor commands, while the system’s core components include stepper motors, a servo motor, L293D motor driver, jumper wires, and a working platform also some equipment need to be establishment of CNC.

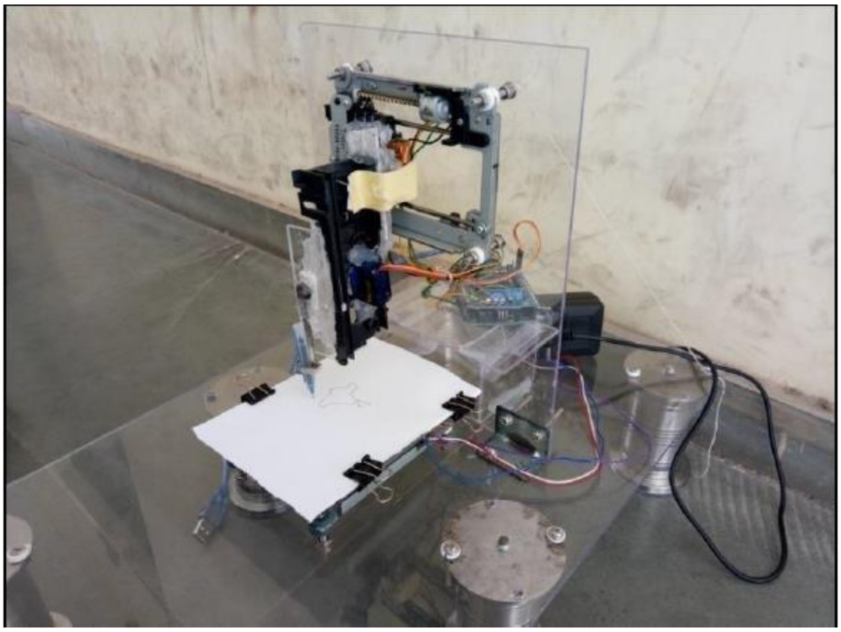

Fig. 1 2D-CNC plotter

1.1 Introduction about Arduino Uno

Arduino is an open-source microcontroller platform that receives commands or data from a computer through a USB cable. It is mounted on a CNC shield, which allows communication between the Arduino and the stepper drivers. The **Arduino UNO** board contains all the essential components to operate the microcontroller. By simply connecting it to a computer via USB and supplying power, it can control the movement of stepper motors through preloaded programs [7]. Designed for ease of use, both in terms of hardware and software, Arduino features digital and analog input/output pins that can connect to various expansion modules, external circuits, and components, enabling flexible programming and integration [8]. The board typically operates on 5 volts supplied through the USB connection.

Fig. 2 Arduino Uno Microcontroller

1.4. L293D motor driver

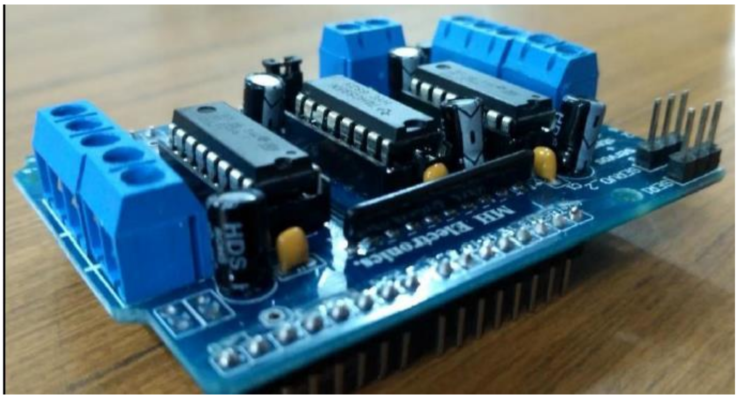

Fig. 3: L293D motor drive

The L293D is a commonly used motor driver integrated circuit (IC) designed to control the rotation of DC motors in both forward and reverse directions. This 16-pin IC can drive two DC motors at the same time, providing separate directional control for each motor.

1.5. Introduction about Mini Servo Motor

A mini servo motor is a compact and lightweight actuator widely used in electronics, robotics, and automation projects. It operates through a control signal that determines the angle of rotation, typically within a range of 0 to 180 degrees [9]. Due to its small size, precise control, and ease of integration with microcontrollers like Arduino, it is ideal for applications such as robotic arms, remote-controlled vehicles, and hobby electronics. Mini servo motors combine a DC motor, gear mechanism, and control circuit in one unit, allowing for accurate positioning and smooth motion control.

Fig. 4. Mini Servo Motor

1.4. Introduction about Stepper Motors

A stepper motor translates digital pulses into precise pen movements along the X, Y, and Z axes. This type of motor is brushless and operates by dividing a complete rotation into equal steps, allowing for accurate control of shaft position with each pulse. In our setup, three stepper motors are used, each paired with a lead screw. The rotational output of the motor drives the lead screw, resulting in controlled linear motion.

Fig. 5: stepper motor

1.5. Introduction about Preparatory Function

G-codes, often denoted by the letter "G," are predefined commands that control the movement of a machine's axes [2]. These codes typically consist of two digits, such as G00, G81, or G90. Multiple G-codes can be included within a single block, as long as they do not conflict with each other [3]. For instance, combining G02 and G03 in one block is not allowed, since they represent opposite motions. G-codes are essential in defining the toolpath for a complete design. Common G-code commands include G00 for rapid movement, G01 for linear motion, G02 and G03 for clockwise and counterclockwise circular interpolation respectively, and G04 for inserting a programmed pause or dwell.

1.6. Problem definition

Most existing Arduino-controlled CNC machines are limited to two-axis movement. Their structural design lacks rigidity, making them suitable only for machining soft materials like foam.

2. METHODS AND MATERIALS

2.1. Design Procedure

The foundational concept behind the mini CNC machine design stems from earlier work focused on building a prototype CNC system operated via a PC, using a cost-effective embedded microcontroller and LABVIEW for control [10]. The mini CNC 2D sketching device is designed to perform movements along three axes. The X and Y axis motions are handled by two stepper motors, enabling accurate positioning of a pen or pencil used for sketching architectural or technical drawings. The vertical (Z-axis) movement—raising or lowering the pen—is managed by a servo motor. Achieving smooth and synchronized operation across all three axes is critical, especially during continuous drawing or printing tasks. These coordinated motions are governed by G-code instructions, which can either be manually written or generated using software like Inkscape [11]. The G-code can be uploaded to the microcontroller by various methods. Inkscape, an open-source vector graphics editor, supports the creation and modification of sketches, line diagrams, logos, and even intricate illustrations. It is capable of converting images into G-code formats (such as Gerber files) required for 2D plotting tasks. A key advantage of using Inkscape lies in its ability to transform sketches through actions like rotation, scaling, movement, and skewing—essential features for clients requesting customized building plans. Fig. 1 illustrates the user interface of the Inkscape software.2.2. Components Used in CNC 2D Sketcher.

2.2.1. CD / DVD Writers

The sketching pen in the CNC 2D plotter must move along both the X and Y axes to accurately draw or print the required design on an A4 sheet. These directional movements are facilitated using two stepper motors, which are repurposed from functioning CD/DVD drives, as illustrated in Fig. 6.

\ 

Fig.6. CD / DVD writer

2. MINI CNC 2D SKETCHER

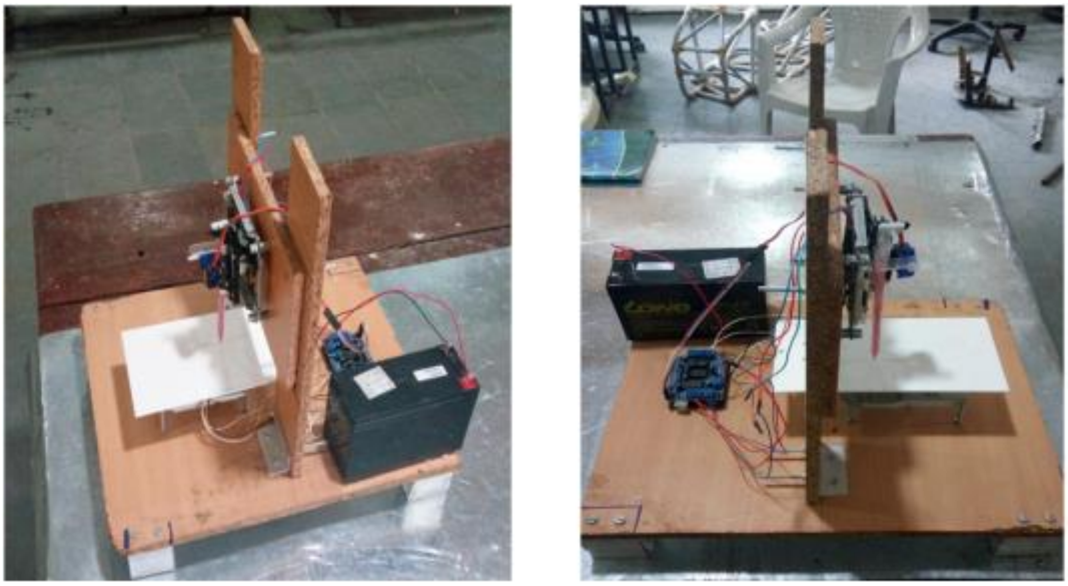

Fig. 7. Mini CNC 2D Sketcher

The designed CNC 2D sketcher illustrated in Fig. 7 is developed to perform essential CNC machine operations such as automated, accurate, and repeatable motion control. The movement of the sketch pen, used for producing building plans or drawings, is controlled automatically by interpreting G-code through a microcontroller. Precise and automated movement along the X, Y, and Z axes is achieved using a combination of one servo motor and two stepper motors. Motor drivers convert signals from the microcontroller into clockwise or counterclockwise motor actions to direct the pen's motion as required. An A4 sheet is secured on the sketching platform using tape at its corners[12]. G-code instructions, either generated manually or via Inkscape software, are loaded onto the microcontroller (ATmega328P), which then sends control signals to the respective components to execute the drawing task. The resulting output—such as building plans, elevations, and other architectural views—is depicted in Fig. 1.

4. OTHER APPLICATIONS

4.1. Metal Removal

The proposed CNC 2D sketcher can be adapted for use in metal-cutting industries to machine raw materials into precise, small-scale automotive and industrial components.

4.2. Metal Fabricating

In the fabrication industry, machining tasks on metal bars or plates are commonly carried out using CNC lathes or milling machines, with similar CNC milling techniques increasingly applied in the modern production of turbine blades. [13].

4.3. Electrical Discharge Machining (EDM)

The proposed CNC 2D sketcher can be adapted for industrial applications, such as electrical discharge machining, which removes metal through thermal erosion, and electron beam melting for precision metal fabrication. [14].

4.4. Other Industries

CNC machines are extensively used in industries such as woodworking, where they perform tasks like routing, drilling, engraving, and lettering.

5. CONCLUSION

Although numerous CAD software tools are available for creating architectural and production drawings—such as plans, elevations, and various views—the developed CNC 2D sketcher offers a versatile alternative for generating customized building drawings based on client requirements. Any necessary alterations to the drawings can be made either by manually editing the G-code or by using Inkscape software for automatic generation. This CNC 2D sketcher enables immediate sketching or printing of building layouts on A4 sheets. Its functionality can also be extended to applications like PCB pattern creation and drilling, Electrical Discharge Machining (EDM), material removal and fabrication tasks, as well as engraving text and logos.

REFERENCES

1. Abd Rahman, Z., Mohamed, S. B., Zulkifli, A. R., Kasim, M. S., & Mohamad, W. N. F. (2021). Design and fabrication of a PC-based 3 axis CNC milling machine. International Journal of Engineering Trends and Technology, 69(9), 1-13.
2. Latif, K., Adam, A., Yusof, Y., & Kadir, A. Z. A. (2021). A review of G code, STEP, STEP-NC, and open architecture control technologies based embedded CNC systems. The International Journal of Advanced Manufacturing Technology, 114, 2549-2566.
3. Ramesh, V., Karthik, K., Arunkumar, K., Unnam, N. K., Ganesh, R., & Rajkumar, C. (2023). Effect of sawdust filler with Kevlar/basalt fiber on the mechanical properties epoxy–based polymer composite materials. Materials Today: Proceedings, 72, 2225-2230.
4. Bevara, S., Amrita, M., Kumar, S., & Kamesh, B. (2020). Effect of graphene nanofluid on machining inconel 718. In Advances in applied mechanical engineering: select proceedings of ICAMER 2019 (pp. 913-920). Springer Singapore.
5. Hashan, A. M., Haidari, A., Saha, S., & Paul, T. (2021). Computer numerically controlled drawing robot based on computer-aided design. Journal of Mechanical, Civil and Industrial Engineering, 2(1), 06-10.
6. Khanduja, P., Bhargave, H., Babbar, A., Pundir, P., & Sharma, A. (2021, August). Development of two-dimensional plotter using programmable logic controller and human machine interface. In Journal of Physics: Conference Series (Vol. 1950, No. 1, p. 012012). IOP Publishing.
7. Tamilselvan, S., Yogeshwaran, K., Pradheep, K., & Udayakumar, E. (2020, July). Development of Artificial Intelligence based assessment writing Robot for disable people. In 2020 7th International Conference on Smart Structures and Systems (ICSSS) (pp. 1-6). IEEE.
8. ElMelegy, A., Zahwi, S., & Sobhy, A. (2024). On straightness measurements of large CNC machine tools. Scientific Reports, 14(1), 13974.
9. Ayanlade, J., Ayanwunmi, V., Omoniyi, P., & Jen, T. C. (2023, November). Exploring creative applications in the digital age: A review of computer numerical controlled plotter. In 2023 2nd International Conference on Multidisciplinary Engineering and Applied Science (ICMEAS) (Vol. 1, pp. 1-5). IEEE.

10. Ramesh, V., Karthik, K., Arunkumar, K., Unnam, N. K., Ganesh, R., & Rajkumar, C. (2023). Effect of sawdust filler with Kevlar/basalt fiber on the mechanical properties epoxy–based polymer composite materials. Materials Today: Proceedings, 72, 2225-2230.
11. Zafar, Z. A., Abbas, T., Rafiq, M., Khan, N., Ahmed, S., & Jadoon, N. R. (2024). STEP-NC compliant 3-axis CNC machine controller based on Field-Programmable Gate Arrays. International Journal of Computer Integrated Manufacturing, 1-19.
12. Ayanlade, J., Ayanwunmi, V., Omoniyi, P., & Jen, T. C. (2023, November). Exploring creative applications in the digital age: A review of computer numerical controlled plotter. In 2023 2nd International Conference on Multidisciplinary Engineering and Applied Science (ICMEAS) (Vol. 1, pp. 1-5). IEEE.
13. Yadav, S., Kumar, S., & Goyal, M. (2024). Trajectory control and optimization of PID controller parameters for dual-arms with a single-link underwater robot manipulator. Journal of the Chinese Institute of Engineers, 47(7), 830-840.
14. Kaur, P. (2024). Optimizing bionic Dual-Arm Underwater Robot Manipulator Performance: A Whales Optimization Algorithm Approach to PID Tuning. J. Electrical Systems, 20(10s), 3350-3361.