Plotting Precision: Exploring the Capabilities of XY Plotters in Modern Research

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Abstract

A XY Plotter machine is purposed in this paper to produce precise and consistent graphical output for customers. It consists of two axis which are perpendicular to each other, each axis has a motorized carriage which moves independently. The precision and accuracy of the axis arms movement allow it to produce detailed drawings, graphs, diagrams. XY Plotter fulfils the industry's demand for accuracy and precision. The XY plotter is flexible to draw on solid surfaces like paper, fabric, vinyl, cardstock, etc. XY Plotter are generally faster manual drawing.it can do draw the same task within a fraction of time required for person to do the same task. It then explores the most recent advances in hardware design, emphasizing improvements in modular construction, precision engineering, and integration with complementary technologies like automation and robotics. The paper examines current advancements in material science, production techniques, mechanical structure, and hardware design. Additionally, it looks at how cutting-edge pen holders, linear guides, and high-resolution stepper motors can be integrated to improve precision and dependability. XY plotter can be used for a wide range of applications like CAD Drawing, circuit schematics, architecture plans, decorative designs.

Keywords: XY Plotter, motorized carriage, graphic output, high precision.

INTRODUCTION

Even though XY plotters have been available for a while, drawing on 2D surfaces is still commonly done using them. Traditional 2D plotters, however, have a lot of drawbacks. The XY 2D plotter is important because it can automate and simplify the process of generating accurate and reliable graphical output. Its high resolution and repeatability make it a crucial tool for industries that demand accuracy and reproducibility. The plotter's flexibility to work with various media types, such as paper, cardstock, vinyl, and fabric, further extends its utility.

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The XY 2D plotter is a precision drawing and plotting device that creates graphical representations of data or designs on a 2D plane. It is made up of the X and Y perpendicular axes, each of which has an autonomously moving motorized carriage. The precision and accuracy of the plotter's movement allows it to produce intricate and detailed drawings, graphs, and diagrams.

LITERATURE REVIEW

There are some examples of previous studies and research related to XY-plotter Machine is shown below in Table-1.

**Table 1.** Some articles related to XY-Plotter Machine

Paper Name	Author Name	Details
XY Plotter machine design with special liner and tilt motion using Arduino uno [1]	T sweyo, S Sudarman, M karomi	XY Axis, G code Potter machine
Modern design and implementation of xy plotter [2]	Rr jegan, e gnansundaram	For every day activities and special document purpose
Application with XY plotter controlled by plc used in student laboratory [3]	M Rata, G Rata	PlcC + HMI System, Works More practical

PROPOSED METHOD

The Proposed method of XY plotter is to use Arduino uno board to collect the G code, which is used to control the 2D Plotters, and send the calculated data to motor drivers. These motors Drivers Drive the motor according to the X, Y co-ordinates, these axes are interconnected using a pen or another drawing tool. Which draws the input image in the given surface.

XY Plotter –

The block diagram of XY plotter is shown below in figure 1.
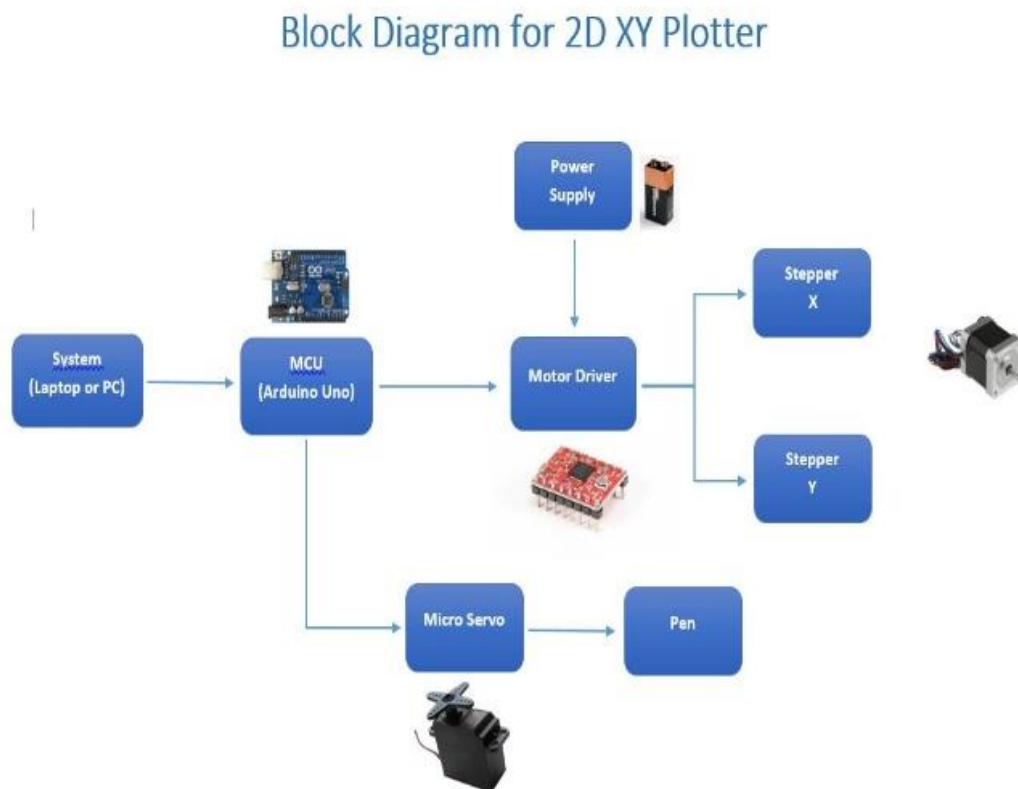
Figure 1. Block Diagram

Hardware

Arduino-Uno

An XY plotter machine is controlled by an Arduino Uno. It accepts commands from the user, moves stepper motors in the X and Y axes, applies motion control algorithms for accurate positioning, connects to sensors for feedback, manages communication with other devices, and permits the user to customize and extend the capabilities of the machine [8].

Description of Arduino-Uno board (Figure-2)-
1. Arduino Uno is a microcontroller board based on the ATmega328P(datasheet).
2. It has 14 digital input/output pins
3. Operation Voltage: 5V
4. Flash Memory: 32 KB
5. Frequency: 16MHz
6. SRAM: 2KB
7. EPROM: 1KB

Figure 2. Arduino-UNO Board

L239D motor drive shield

   The Arduino Uno and the stepper motors in an XY plotter machine are interfaced with by the L293D motor drive shield. It includes protective features, amplifies current, facilitates bidirectional movement, and simplifies motor control. Description of L239D motor drive shield (Figure-3).

1. L293D motor drive chip
2. Terminal block for power supply and DC motors
3. Four H- Bridges
4. PCB size: 69x 53 mm
5. Reset button
6. Terminal Block Connectors

Figure 3. L239D Motor Drive Shield
L239D Motor Drive IC
   It simplifies wiring and ensures compatibility with microcontrollers like Arduino Uno, contributing to efficient operation. (Figure-4).

1. Motor voltage Vcc2 : 4.5V to 36V
2. Maximum Peak motor current: 1.2 A
3. Maximum continuous Motor Current: 600 mA
4. Supply Voltage to Vcc1 : 4.5V to 7V
5. Transition time: 300ns (at 5Vand 24V)
6. Automatic Thermal shutdown is available
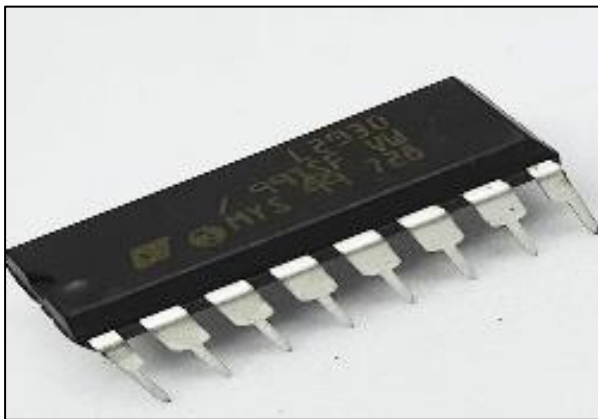
Figure 4. L239D Motor Drive IC

Nema 17 Stepper motor
   The Nema 17 stepper motor (Figure-5) in an XY plotter machine provides precise, bidirectional movement of the drawing tool along the X and Y axes, ensuring accuracy, stability, and reliability in creating intricate designs.

1. Body Length : 40 mm 2. Shaft Diameter: 5 mm
2. Shaft Length : 23 mm
3. D-cut Length : 21 mm
4. Number of Leads : 4

Figure 5. Nema 17 Stepper motor

MG90S Servo Motor

The MG90S servo motor (figure.6) in an XY plotter machine is typically used for controlling the movement of auxiliary components such as pen lift mechanisms or for adjusting the angle of the drawing tool.

1. Operating Voltage: 4.8V
2. Operating Speed: 0.11 seconds / 60 degrees (4.8V)
3. Temperature Range: 0-55 ℃
4. The dead-band setting: 5 microseconds
5. Line Length: 250MM

Figure 6. MG90S Servo Motor

GT2 Pulley 16 Teeth

The GT2 Pulley with 16 teeth (Figure.7) in an XY plotter machine is integral for transmitting motion from stepper motors to the timing belt.

1. Teeth No.: 16
2. Tooth Pitch: 2mm (GT2)
3. Bore Diameter: 5mm
4. Flange: Double
5. Tooth Width: 7mm
6. M3 Grub Screws included

Figure 7. GT2 Pulley 16 Teeth

GT2 Rubber Belt

The GT2 rubber belt (figure.8) in an XY plotter machine is responsible for transmitting motion from the stepper motors to the moving components, such as the carriage carrying the drawing tool.

1. Pitch: 2mm
2. Width: 6mm
3. Belt Height: 1.52mm
4. Tooth Height: 0.76mm
5. Type: Closed-loop / Endless

Figure 8. GT2 Rubber Belt

Software Components

Inkscape software

The use of Inkscape (figure 9) in 2D plotters provides useful features for design creation and G-code generation. For creating and altering vector-based drawings, Inkscape, a well-known open-source vector graphics editor, offers an intuitive user interface along with an extensive toolkit.

Users can transform their designs into G-code instructions, which are frequently used to drive CNC machines, including some 2D plotters, by using the G code tools plugin, which was created especially for Inkscape. Using shapes, lines, text, and imported pictures, users may create complex designs with Inkscape's design creation features. Additionally, the program has strong route editing tools that let users precisely manipulate curves and forms to create intricate designs that may be plotted. By adding the G code tools plugin, Inkscape turns into a useful tool for creating G-code files with 2D plotter instructions. The G-code generating process can be tailored by users by adjusting factors including feed rates, cutting depth, and tool selection. Plotter control can be achieved with ease by exporting the design as a G-code file, which facilitates a smooth transition from the design generation stage [5-7].
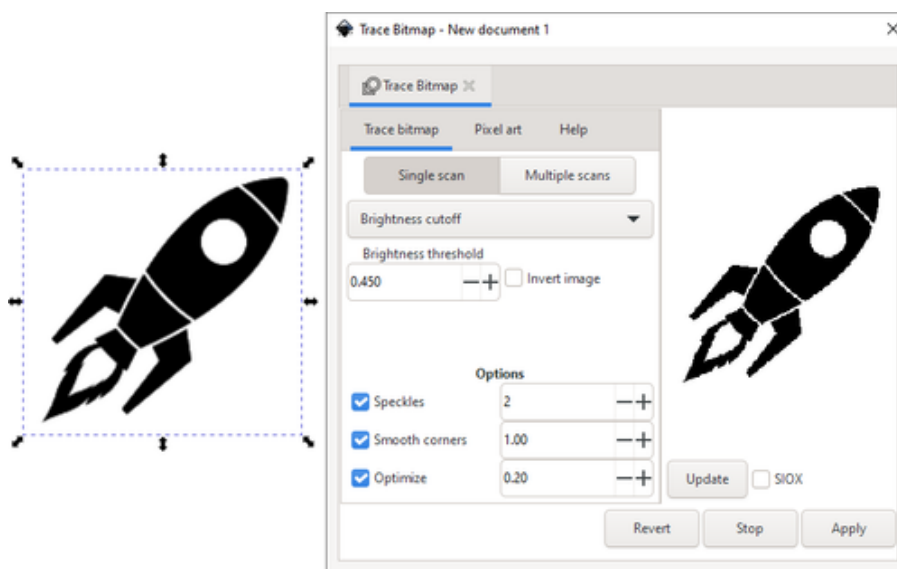
Figure 9. Screenshot of Inkscape software

Universal G Code Sender

Figure 10 illustrates the Universal G code Sender (UGS), a software program frequently used to operate 2D plotters. Plotters can be connected to, G-code files can be loaded, and directions for exact motions and actions may be sent. Essential features offered by UGS include job scheduling, error handling, connection management, real-time monitoring, and recovery options. UGS guarantees precise results and makes handling a 2D plotter easier thanks to its user-friendly interface. The following advantages of integrating UGS with GRBL firmware can be attained: 1. interoperability: GRBL firmware offers smooth interoperability with UGS and is well-suited for 2D plotters. This enables users to take advantage of GRBL's sophisticated capabilities, like motion planning, homing, and acceleration, for accurate and effective charting. 2. Real-time Feedback: To give real-time input on the plotter's position, progress, and status, GRBL talks with UGS. This makes it possible for users to keep a close eye on the charting process and amend or intervene as needed [9].
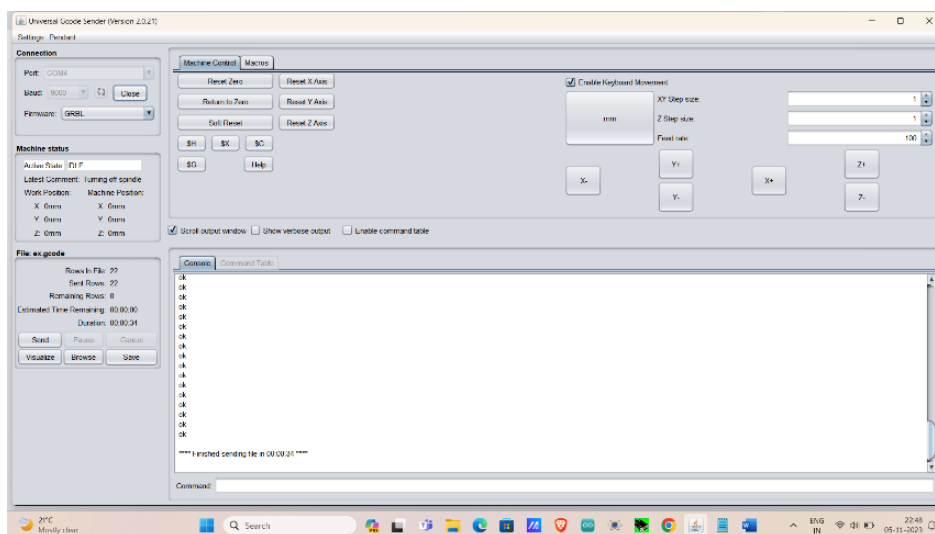
Figure 10. Screenshot of Universal G Code Sender

METHODOLOGY

Hardware Development: The first step is to develop the hardware for XY plotter, this will involve prototyping and designing of the following components:

1. Arduino Uno R3
2. L293D Motor Driver Shield
3. L293D Motor Driver IC
4. Nema17 Stepper Motor
5. MG90S Servo Motor
6. GT2 Pulley 16 Teeth
7. GT2 Rubber Belt

The XY Plotter hardware should be designed robustly to withstand the demands of the XY Plotter environment. The Servo motors should be able to move accurately in any environmental conditions.

Mechanical Assembly: Build the frame for your XY plotter, ensuring that it's stable and that the rails and carriages for both X and Y axes are securely attached One stepper motor for the X- and Y-axes should be attached to the frame. To enable movement in both the X and Y directions, install the pen holder mechanism [3].

Electrical Wiring: Connect the stepper motors to the controller board. Stepper motors typically have

four wires, which need to be connected to the appropriate motor driver outputs on the controller board. Connect the controller board to the power supply and ensure it provides the correct voltage and current for the motors.

Programming and Software: Write or use software to control the plotter. This software should convert your desired drawings or images into G-code, which is a language that the plotter understands. Upload the G-code to the controller board. The G-code commands will specify the movement of the pen to create the drawing.

Calibration: Calibrate the plotter by setting the home position and defining the plotter's workspace dimensions. Adjust the mechanical components and fine-tune the software to ensure accurate drawing [4].

Drawing: Load the paper or drawing surface onto the plotter. Start the plotter, and it will follow the G-code instructions to draw your desired image or design.

Maintenance: Make sure the pen is secure and working properly, lubricate moving parts, and check for loose connections when you routinely maintain the plotter.

RESULT & DISCUSSION
Simulation Result: The designed G-code was delivered to the X-Y Plotter Machine. The plotted input diagram, G-code are all provided below in figure-11 and Figure 12.
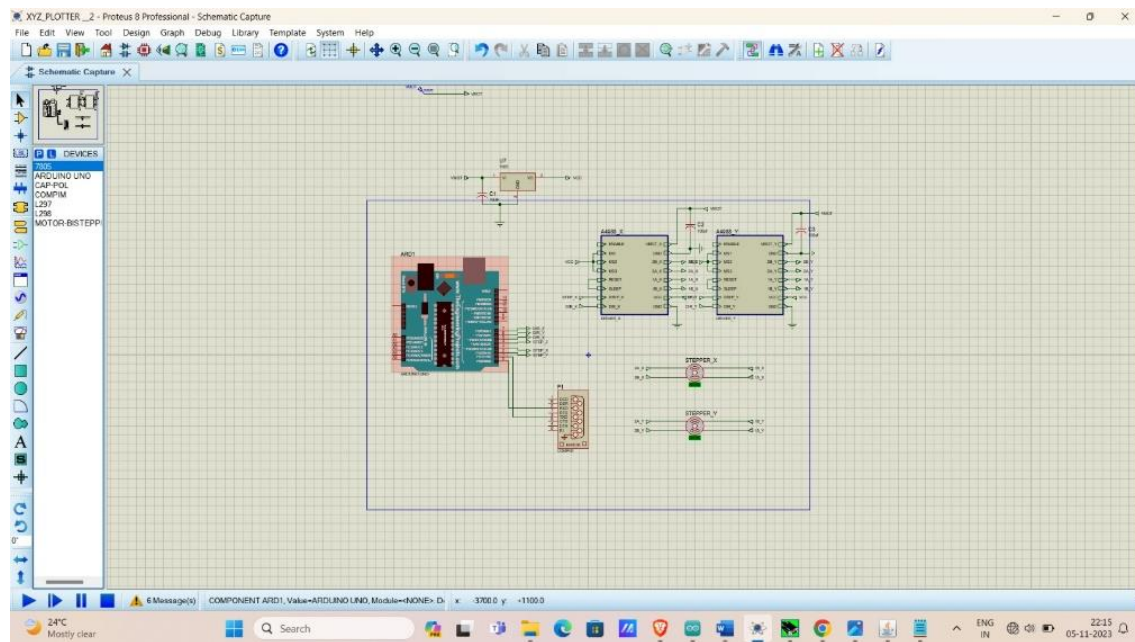
Figure 11. Proteus Simulation

Hardware Result:

Figure 12. Result.

APPLICATIONS
1. PCB design
2. CNC Machine
3. Logo design
4. Drawing Art
5. Writing on 2D solid Surface
6. Laser cutting

CONCLUSION
Impressive levels of accuracy and precision were displayed by the XY plotter when converting digital designs into physical drawings.

By carefully calibrating and fine-tuning the system, we achieved minimal errors in position, alignment, and scale, resulting in crisp and detailed drawings. Speed and Efficiency: The optimization of the XY plotter's mechanical and software components led to remarkable speed and efficiency gains. It can now produce drawings of complex designs in a fraction of the time it previously required, making it a highly productive tool for various applications.

Acknowledgement

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