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Design and Implementation of an Arduino-Based 2D Plotter Machine Controlled by Universal G-Code Sender (UGS)

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Abstract – The design, development, and analysis of a precision XY plotter system that can use controlled mechanical motion to convert digital graphical inputs into physical representations are presented in this paper. Stepper motor-driven mechanisms are used to achieve positioning, and the system functions on the principle of coordinated displacement along two orthogonal axes. In order to drive actuators, a control unit decodes motion instructions encoded in standard command format and produces the appropriate electrical signals.

Accurate trajectory tracking and repeatable output generation are made possible by the integration of electrical circuitry, mechanical transmission, and software processing. The study also looks at how the system behaves in terms of operational stability, synchronization, and resolution. The created system provides a useful framework for comprehending the real-world application of motion control systems.

Keywords: XY Plotter, Motion Control System, Stepper Motor, G-Code, Positioning System, Automation, CNC Principle

1. Introduction

In the context of modern engineering applications, the need for precise and repeatable motion has resulted in the development of different types of automated systems. These types of machines that are capable of making precise movements are commonly used in the manufacturing, printing, and design sectors. Of these, the plotting system has a major role in the conversion of digital information into graphical representations.

An XY Plotter is a position-controlled device that operates on the basis of coordinate geometry. The movement of the tool, also known as the pen, is determined in terms of the displacement in the horizontal and vertical directions. The device reads the input information and converts it into a motion command, which is further executed by the actuators.

The importance of the XY Plotter lies in its ability to explain the different concepts of motion control, including step generation, synchronization, and trajectory planning. This paper aims at the development of a compact and functional plotter system.

2. System Overview

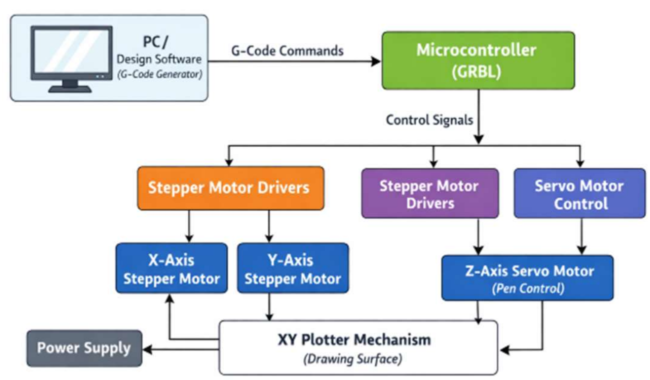

Fig. 1: Block Diagram of the Proposed XY Plotter System

The system consists of three main subsystems: the input processing system, the control unit, and the motion execution system.

The input system processes the graphical data into a command format. The control unit processes the command and generates the required electric signals. The motion execution system consists of the motor and the mechanical linkages.

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The relationship between the three systems creates a close operational loop. The efficiency of the system depends on the synchronization between the three steps.

3. Circuit Design and Electrical System

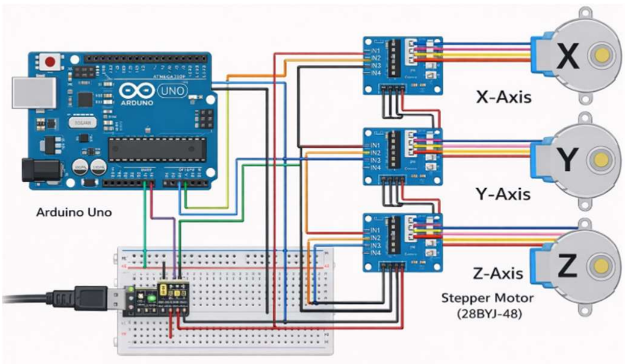

Fig. 2: Circuit Diagram of the XY Plotter Control System

The electrical system serves as the central controlling layer in the plotter. Its functions include ensuring coordination between input commands and mechanical motion. The electrical system consists of a controller, motor driver circuits, a power supply system, and an interconnection network.

The controller receives input instructions and sends corresponding signals. The signals take the form of pulses. The pulses represent how much a stepper motor moves. The pulses also represent how fast the motor moves. The stepper motor drivers act as an interface between the controller and the motor. The drivers cannot be sent signals by the controller; they need to be amplified and sent at appropriate levels. The drivers also protect the controller from electrical overload and voltage changes. The servo motor is controlled by pulse width modulation. The motor lifts and lowers the pen using PWM. The angle of rotation is controlled by changing the pulse width. The angle is used to lower and lift the pen.

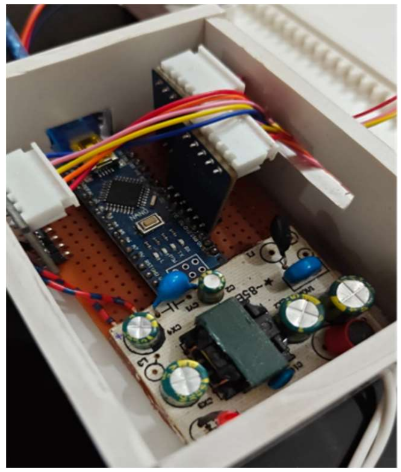

Fig. 3 Mechanical Structure of the XY Plotter

The power supply unit is designed to provide a regulated voltage to all components in the system. Fluctuating voltages can result in unpredictable motor action, so filtering components like capacitors are used to regulate the supply.

The implementation of a printed circuit board improves the reliability of the system through secure connections, reducing noise, and improving overall performance. Proper grounding and layout design are essential to avoid signal interference.

4. Hardware Implementation

4.1 Complete System Setup

The hardware system is designed in a manner that ensures both mechanical and electrical parts are integrated in a proper manner so that smooth, reliable, and continuous operation is possible. Proper placement of parts is given due consideration so that the movement of X, Y, and Z axes is not hampered by wiring, connectors, or structural parts. This ensures free movement of the machine so that there is no friction or resistance in its functioning.

The design of the system mainly aims at achieving structural rigidity so that all moving parts are aligned properly. Rigidity of the frame is necessary in order to minimize vibrations that may be caused by motor functioning. These may interfere with the accuracy of the output. Stability is a very important factor in this machine, as even slight vibrations may cause deviation in the output, especially when detailing is required.

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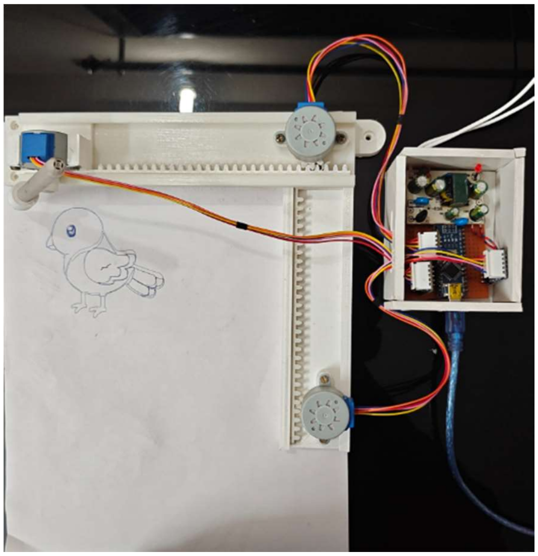

Fig. 4: Complete Hardware Setup of the XY Plotter System

4.2 Actuation System

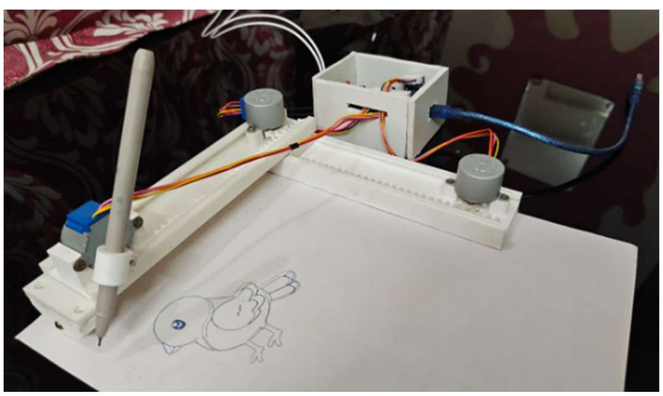

Fig. 5: XY Plotter System During Drawing Operation

The actuation system is in charge of translating electrical signals into motion. This includes a linear motion provided by a stepper motor and a servo motor for pen control. The stepper motor works on a principle of stepping rotation. Every rotation is equal to a given angular displacement, and this is translated into linear motion. The stepper motor is controlled by two main factors: the number of steps and the step frequency. This ensures that both speed and accuracy are achieved. The servo motor is used for angular motion over a given range. It is used for lifting and lowering the pen. This ensures that it is lowered only when it is necessary to draw. The synchronization of all motors is very important for this system.

5. Mechanical Design

5.1 Structure Design

The mechanical structure acts as the base for the plotter system. It is designed to provide support, alignment, and stability to all the moving parts. The mechanical structure consists of a stiff framework to ensure that there is little or no deformation during movement, allowing the parts to move in specific directions.

The alignment of the axis in the plotter system is very important to ensure accuracy. Deviation in axis alignment can result in errors in the output.

5.2 Motion Transmission Mechanism

The motion transmission system is used for the conversion of rotational motion into linear displacement. This is done by a gear-based system. The accuracy of this system is influenced by several factors, including gear ratios, gear alignment, and backlash. Backlash is a slight degree of play in the meshing of two gears. This can cause inaccuracy in positioning. The choice of transmission mechanism is significant in determining the efficiency of a system.

6. Software and Control Process

The role of the software system in translating user input into machine-readable instructions is significant. There are several stages in this system, including image processing, code generation, and command execution. At first, vector graphics are developed, in which the paths that are to be followed by the pen are defined. These paths are then translated into G-code, in which detailed information regarding the movement, speed, and positioning of the pen is provided. This G-code is then sent to the controller, where each command is interpreted, and corresponding electrical signals are developed. There is a need for proper timing in executing these commands. There is a provision for adjustments, which provides more flexibility to the system.

6.1 Real-Time Execution

In the course of real-time operation, the system processes the commands in sequence. The controller receives each command and produces pulses to drive the motors appropriately. The synchronization of the motors in the process ensures accurate tracking of the trajectory. However, any form of delay in the execution of the commands can result in distortion in the output.

The performance of the system in the course of real-time processing depends on the efficiency in managing the commands.

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7. Theoretical Analysis

The principles behind the operation of the plotter system include motion control, electromechanical energy conversion, and coordinate geometry. The location of the pen is determined by its movement in one dimension. The determination of location in one dimension is based on Cartesian motion.

A stepper motor is controlled by energizing the windings in steps. The rotation occurs in steps. The rotation is controlled in such a way that it is precise. The precision is achieved by controlling the steps. The steps are converted to linear motion.

The relationship between electrical input and mechanical output is based on pulses. The pulses represent steps. The steps represent the rotation. The rotation is determined by the pulses. The pulses determine the speed. The direction is determined by the flow of current.

The synchronization is achieved by coordinating pulses. The pulses coordinate the rotation. The rotation is achieved by both motors. The motors rotate in such a way that it is controlled. The accuracy is determined by the pulses.

The mechanical factors include friction, backlash, and rigidity. Electrical factors such as signal noise and voltage stability also play a significant role. The overall behavior of the system is a combination of these factors.

8. Results and Discussion

The developed system shows that it can convert a digital input into a physical drawing. The output shows that the system can perform well for basic shapes and patterns. It can run at a moderate speed; at higher speeds, it shows minor deviations. The repeatability of the system shows that it can run stably.

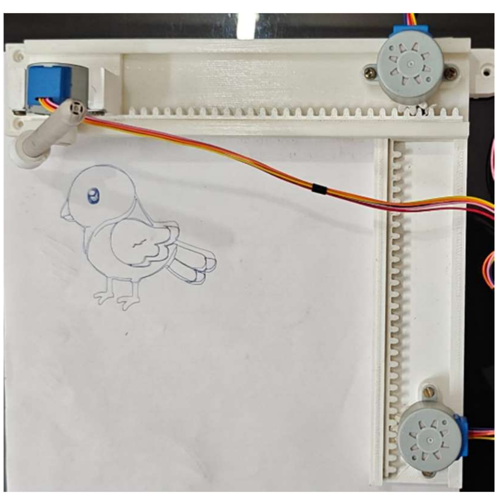

Fig. 6: Generated Drawing Output of the XY Plotter System

9. Conclusion

The developed XY plotter system is a successful application of the integration of motion control systems, electrical systems, and mechanical systems. It is a good example of the translation of digital graphical information into physical output through motion control. The importance of synchronization, calibration, and system stability is emphasized in the study. It offers significant insight into the application of motion control systems and provides a platform for further developments.

10. Future Scope

The performance of this system can also be improved by improving both hardware and control strategies. More precise hardware can be used to make it more accurate and reduce errors. Advanced control techniques like feedback control systems can also be incorporated to make it more reliable. This system can also be extended for other uses such as engraving, cutting, and manufacturing. This system can also be improved using advanced technologies like wireless communication and IoT.

11. References

1. Girhe, P., Yenkar, S., & Chirde, A. (2018). **Arduino Based CNC Plotter Machine.** *International Journal of Emerging Technologies in Engineering Research.*
2. Hasan, M. M., Khan, M. R., Noman, A. T., Rashid, H., & Ahmed, N. (2019). **Design and Implementation of a Microcontroller-Based CNC Plotter.** *International Conference on Electrical, Computer and Communication Engineering (IEEE).*
3. Suresh, R., et al. (2025). **Design and Implementation of 2D CNC Plotter.** *International Journal of Research and Scientific Innovation.*
4. Hyder, S. F., Ibrahim, M., Adan, M. Z., & Mohammed, F. (2020). **CNC Plotter Machine.** *Research Journal of Engineering and Technology.*
5. Jabri, M. (2022). **CNC Plotter Machine Design and Development.** *Engineering Research Repository.*