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CNC Polar Plotter

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Abstract- *CNC plotter machines are widely used for automated drawing and precision-based applications in engineering and design fields. This project presents the design and fabrication of a low-cost CNC Polar Plotter developed using readily available and recycled components. Unlike conventional Cartesian CNC plotters that rely on X–Y linear motion, the proposed system operates on a polar coordinate mechanism, which significantly reduces mechanical complexity and overall cost. An Arduino Nano is used as the main controller to coordinate the motion of a 28BYJ-48 stepper motor for angular movement and a servo motor for pen lifting operations. Additional components such as a ULN2003 driver, DVD BLDC motor, bicycle wheel spokes as linear guides, and an LM2596 buck converter are employed to enhance efficiency and stability. The developed system is capable of accurately drawing two-dimensional geometric patterns and images. The results demonstrate that the CNC polar plotter provides reliable performance with acceptable accuracy, making it suitable for educational, prototype, and low-cost automation applications.*
Keywords- *Arduino Nano, CNC, stepper motors, Inkscape software, Gcode file*

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I. INTRODUCTION

Computer Numerical Control (CNC) plotter machines are widely used for automated drawing and precision-based applications. Conventional CNC plotters generally operate using Cartesian coordinates, which require multiple linear axes and complex mechanical structures. This increases the overall cost and system complexity.

To overcome these limitations, a polar coordinate–based CNC plotter can be employed, where motion is achieved through angular rotation and radial displacement. This approach reduces mechanical components while maintaining acceptable accuracy. In this research paper, a low-cost CNC Polar Plotter is designed using an Arduino Nano, stepper motor, servo motor, and other readily available components. The developed system offers a simple, economical, and efficient solution for educational and small-scale drawing applications

II. LITERATURE SURVEY

In this section, a brief summary of the research carried out by various authors on CNC Polar plotter machines is mentioned. 1] J. J. Craig and P. C. Watson (2016), “Polar Coordinate Plotting Systems for Educational Applications”.

The objective of this research paper is to study the implementation of plotting systems based on polar coordinates. This research provided an understanding of how angular and radial movements can replace traditional X–Y Cartesian motion while maintaining acceptable plotting accuracy.

[2] Prince Mohammad, Muhsi-Al Ansary, and Abu Mondol (2017), “Implementation of a Low-Cost CNC Plotter Using Spare Parts”.

The goal of this research paper is to design a low-cost CNC plotter using recycled components. This study gave insight into minimizing system cost by reusing motors and mechanical parts, which is relevant to the development of economical CNC polar plotter systems.

[3] Aman Nsayef and Anas Lateef (2018), “Microcontroller-Based Plotter Machine”.

The objective of this research work is to develop a microcontroller-controlled plotter machine for basic drawing applications. This paper helped in understanding stepper motor control techniques and simplified motion algorithms applicable to polar-based plotting mechanisms.

[4] Raad Sara, Haider Mohammad, and Mustafa Falah (2019), “Accurate and Cost-Effective Mini CNC Plotter”.

The goal of this research paper is to achieve accurate plotting using minimum hardware resources. The work emphasized reducing mechanical complexity, which supports the concept of using polar coordinate motion instead of conventional Cartesian systems.

[5] M. Aditi, S. Karpagam, B. Nandini, and B. S. Murugan (2019), “Automated Writing and Drawing Machine”.

The objective of this research is to design an automated drawing system using a microcontroller and motor-based control. This paper provided insights into pen positioning mechanisms and motion coordination techniques useful for CNC polar plotter applications.

III. OBJECTIVE

The objective of this research paper is to design and fabricate a low-cost CNC Polar Plotter capable of performing accurate two-dimensional drawing operations using a polar coordinate system. The proposed system aims to reduce mechanical complexity and overall cost when compared to conventional Cartesian CNC plotters by minimizing the number of linear motion components. The project focuses on the effective use of readily available and recycled components along with an Arduino Nano for precise motor control. The developed CNC polar plotter is intended to serve as a compact, economical, and efficient solution for educational, research, and small-scale automation applications.

IV. BLOCK DIAGRAM

The CNC Polar Plotter operates based on control signals generated by the Arduino Nano, which acts as the main control unit of the system. The required power is supplied using a 12 V adapter, and voltage regulation is achieved through an LM2596 buck converter. The Arduino sends control signals to the ULN2003 driver, which drives the 28BYJ-48 stepper motor to provide angular motion for polar plotting. A servo motor is used to control the pen up and down movement during drawing. The coordinated functioning of the controller, driver, motors, and power supply enables accurate and automated plotting.

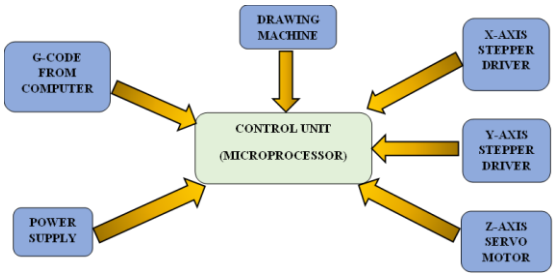

Fig 1. BLOCK DIAGRAM OF CNC PLOTTER MACHINE

V. SOFTWARES

A. INKSCAPE SOFTWARE (version 0.92.4)

The Inkscape software will convert any desired image or text into a G-code file. It is a free and open-source vector editor. The main purpose of the software is to trace the images or text. The tracing of the image is carried out by the following steps, open the Inkscape software version 0.92.4 and set the document properties. Further, select the size of the page accordingly millimeter or centimeter (mm or cm) according to your page size, then drag and drop or import the particular image needed. The image can be resized according to the paper size. Now go to Trace bitmap. After trace bitmap, two photos will be available, delete the original one and keep the traced one. After that select go to Path- object to path. Hence, the traced image is obtained which indicates that when will pen or the tool will go up and pen down. The Gcode file obtained can be saved in the desired location.

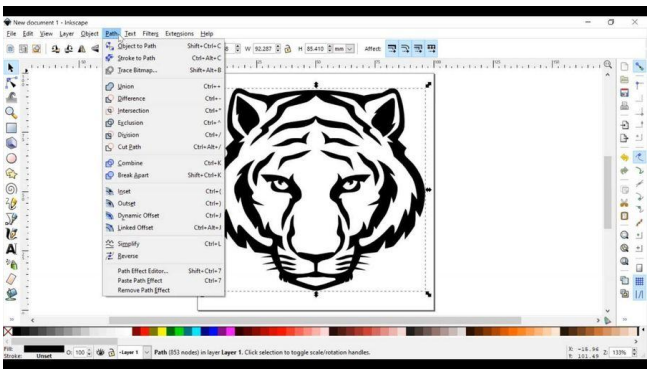

Fig 2. CONVERSION OF IMAGE TO G-CODE FILE

B. ARDUINO IDE 1.8.16

The open-source Arduino Software (IDE) allows us to write code and upload it to the board in real-time. Arduino IDE works within Windows, Mac and Linux operating systems. The Arduino IDE acts as a channel between the computer and the motor drive. The CNC shield and motor shield are used to interface the motor drive.

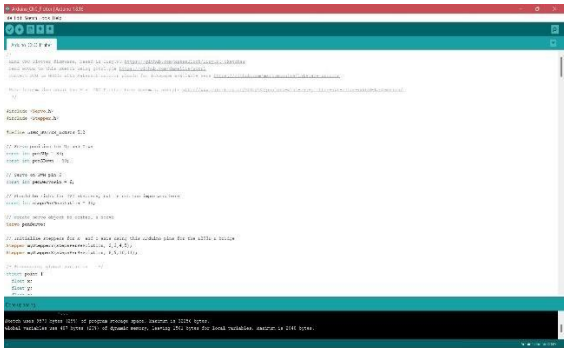

Fig 3. ARDUINO SOFTWARE IDE

VI. HARDWARE COMPONENTS

A. ARDUINO NANO

The Arduino UNO is a microcontroller board that uses the ATmega328P microcontroller. There are 14 digital input/output pins, six analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header, and a reset button on the board. The Arduino utilises the input program to control the movement and the position of the stepper motors.

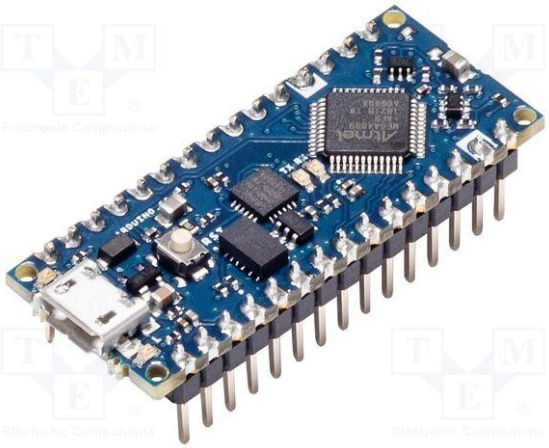

Fig 5. ARDUINO NANO

B. SERVO MOTOR

The servo motor is an electrical device that allows the object to rotate with high precision. It is very commonly used in remote-controlled toys, drones, robots, printing machines, etc. The application of a servo motor in a CNC plotter machine is to control the up and down movement of the pen. This action is implemented by sending pulse width modulation. The pulse value of 90 degrees enables the pen to go up otherwise if the value is as low as 0 degree, the pen goes down. The up and down movement of the pen is in the Z-axis direction.

Fig 6. SERVO MOTOR

D. STEPPER DRIVER

The stepper driver receives a pulse signal and causes the motor to rotate at an angle in a certain direction. In the project, a l293D motor driver has been utilised.

Fig 7. L293D MOTOR DRIVER

E. STEPPER MOTOR

The stepper motor is an integral component in a CNC plotter machine as it controls the precision and speed of the system. It is a brushless and synchronous electric motor. The stepper motor helps to control the precise and accurate movement of the X and Y axes. The movement and position of the stepper motor are carried out without any feedback mechanism i.e., it is based on open-loop control system.

Fig 8. STEPPER MOTOR

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VI. RESULTS

Any input can be given for the CNC machine to execute. The input can be either image or text. Here, (Lion Face) is given as an input and the tool used here is a gel pen. The tool can be replaced as per the requirements.

The stepper motor is an essential component of the CNC polar plotter as it plays a major role in controlling the precision and speed of the system. It is a brushless, synchronous electric motor that moves in discrete step increments, enabling accurate motion control. In the proposed system, the stepper motor is used to provide angular motion required for polar plotting. The position and movement of the stepper motor are controlled without the use of any feedback device, making it an open-loop control system. Due to its high accuracy and repeatability, the stepper motor ensures precise positioning of the drawing mechanism during plotting operations.

VII. CONCLUSION

In this research paper, a low-cost CNC polar plotter was successfully designed and developed using readily available components. The system demonstrates that a polar coordinate-based mechanism can effectively reduce mechanical complexity while maintaining acceptable accuracy for two-dimensional drawing applications. The use of an Arduino Nano, stepper motor, and servo motor enables precise control of angular motion and pen positioning. The developed prototype operates reliably and is economical, compact, and easy to implement, making it suitable for educational purposes, research activities, and small-scale automation tasks.

VIII. FUTURE SCOPE

The performance of the CNC polar plotter can be further enhanced by using higher torque and higher precision motors to improve drawing accuracy. Wireless technologies such as Bluetooth or Wi-Fi can be integrated for remote operation. The system can also be upgraded by incorporating advanced features like laser engraving or PCB plotting for expanded applications. Additionally, increasing the plotting area and improving mechanical rigidity can make the system suitable for more complex and commercial-level tasks.

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