Quantification of the phase fraction in multiphase steel and 2D design using mini CNC plotter

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Abstract. This present experimental setup is about designing a low cost three axis Mini CNC plotter using stepper motor, Arduino microcontroller and motor control software. This present experimental plotter deals with a low cost CNC plotter which can be further modified into small - medium size or an open structure as per the requirement. The demand for Computer Numerical Control (CNC) plotter machines in educational institutions and laboratories are rapidly rising with the advancement of technology. Current investigation will present an affordable model of a CNC plotter machine which is able to draw different microstructural phase fraction identification layout for further FE analysis of multiphase steel, automotive layout and any other solid surface using simple algorithm. First of all, image file or text file is converted into G code using Inkscape software and then feed it to the machine using processing software. The microcontroller converts G-code into a set of machine language instruction to be sent to the motor driver of the CNC plotter. L293D Motor Shield accordingly instructs the stepper motor how to move, combine, and synchronize motions of stepper motor ends in a good image.

Keywords: Computer Numerical Control, Inkscape software, microstructural phase fraction, CNC plotter

1. Introduction

Mini CNC 2D plotter is based on Arduino Nano and L293D motor shield. G codes are the functions generally used in computer numerical control machine. According to the movement of machine the G-code retrieves. Instruction to the design tool in X, Y, Z directions is provided through G-codes. Anything can be used in place of a design tool such as pen, pencils, sketch pen and all as a tool of CNC. The aim of this investigation is to make a mini design tool plotter machine which can draw any design on the writable surface. Two stepper motors with timing belts and pulley in Cartesian coordinate X and Y directions are used for functioning with a greater accuracy and a servo motor for Z axis has been used [1]. CNC is commonly used for cut, etch, mill, engrave, turn and can perform manufacturing operations on various materials. Typically, a CNC machine can move a cutting or printing head in three axes, hence it can position the tool head at a precise point on the material to create the operation desired at that point [2]. The 2D plotter is mainly designed for to plot the
drawings and images. Park et al., [3] discussed the mechanism of dual-drive servo and develop an XY framework model consisting of two motors for Y control with another motor sliding on the framework in X direction.

The main aim of the current work is to make a low cost mini CNC plotter machine and quantification of the phase fraction in steel using mini CNC plotter. Another concern is the accuracy level of the machine. Few literatures have been discussed on plotters in term of their adjustment methods on the accuracy and movement of plotter [4]. Open source microcontroller platform Arduino is used to control of the motors, and it is used for executing the G code for the machining applications. The Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board, an USB cable can be simply used. Under CNC machining, machine tools function through numerical control [5].

2. Model Description
Microcontrollers are interactive devices that can sense and control both physically and digitally. Arduino microcontroller is used as a brain in this current work. Any image file or text file is converted into G code using Inkscape software and then input it to the machine using processing software. Here control device is used Arduino Nano with an ATMega328P microcontroller. The complete mechanical system was designed in the metallic CD drive cover. The three main sections of mini CNC 2D Plotter are hardware, software and industrial design. Electronic hardware consists of interconnected electronic components which perform analog or logic operations on received and locally stored information to produce as output resulting new information to provide control for output actuator mechanisms. Electronic hardware can range from individual chips/circuits to distributed information processing systems. The XY-plotter consists of two axes operating orthogonally to each other. The axes are introduced by a CD drive and a third axis is introduced by a stepper motor. The software system of the current work consists of Inkscape (version 0.48.5), Arduino IDE and Processing 3.0.2. Stepper motors of CD drives are used so that the movement should be very accurate. Y-axis: carries design tool that move from front to back. X-axis: carries design tool that move from left to right. CD drives containing stepper motor are used for X-Y direction co-ordinate movements as shown in the Figure 1. For design tool setup (Z axis) high-density bar board (HDF) is used. It is a type of bar board, which is petroleum by product. It is of light weight. Servomotor is adjusted inside the HDF to get the up and movement required to plot the object. Z-axis: carries design tool part that move up to down. The outer metallic cover of the CD drive is used for holding CD drive in the X and Y axis. All the sections are integrated together to get the complete setup of the plotter. The Figure 2(a) and 2(b) shows the design of the design tool stand and also the view angle of that is side view, Figure 2(a) and also front view, Figure 2(b).

![Figure1. Lens Frame in CD Drive (Containing stepper motor)](attachment://Figure1.png)
The following steps show the building stages of a low cost mini CNC plotter. For X and Y axis, the stepper motors from CD drive is used. Servo motor is used for Z axis. Inkscape, Processing and Arduino IDE provide the command from the computer as G code to the Arduino board to get the plotted output. Figure 3 shows the flow chart of low cost CNC plotter in which the G code of a scanned image enters into the Arduino Nano and Arduino Nano instructs the L293D motor shield which further controls the movement of the stepper and servo motors.

The Arduino Nano is a small, complete, and bread board-friendly board based on the ATmega328 (Arduino Nano 3.x) or ATmega168 (Arduino Nano 2.x). It has more or less the same functionality of the Arduino Duemilanove, but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one. The Arduino Nano can be powered via the Mini-B USB connection, 6-20V unregulated external power supply (pin 30), or 5V regulated external power supply (pin 27). The power source is automatically selected to the highest voltage source. Figure 4 shows the Arduino microcontroller with pin layouts.
Figure 4. Arduino NANO

Table 1: description of arduino microcontroller

| Pin No. | Name | Type | Description                                      |
|---------|------|------|--------------------------------------------------|
| 1-2, 5-16 | D0-D13 | I/O  | Digital input/output port 0 to 13               |
| 3, 28   | RESET | Input | Reset (active low)                              |
| 4, 29   | GND  | PWR  | Supply ground                                    |
| 17      | 3V3  | Output | +3.3V output (from FTDI)                        |
| 18      | AREF | Input | ADC reference                                    |
| 19-26   | A7-A0 | Input | Analog input channel 0 to 7                     |
| 27      | +5V  | Output or | +5V output (from on-board regulator) or |
|         |      | Input  | +5V (input from external power supply)          |
| 30      | VIN  | PWR  | Supply voltage                                   |

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. One can direct the board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on wiring), and the Arduino software (IDE), based on processing. Over the years Arduino has been the brain of thousands of current works, from everyday objects to complex scientific instruments. A world wide community of makers-students, hobbyists, artists, programmers, and professionals has gathered around this open source platform. There are total 30 pins in the Arduino nano, among them 14 are digital i/o pins and 8 analog pins, Reset, Gnd, 3V3, Aref, +5v and a Vin pin. Table 1 shows the description of arduino microcontroller.

The motor driver is a module for motors that allows you to control the working speed and direction of two motors simultaneously. This motor driver is designed and developed based on L293D IC. L293D is a 16 Pin Motor Driver IC. The device is a monolithic integrated high voltage, high current four channel driver designed to accept standard DTL or TTL logic levels and drive inductive loads.
(such as relays solenoids, DC and stepping motors) and switching power transistors. To simplify use as two bridges each pair of channels is equipped with an enable input. A separate supply input is provided for the logic, allowing operation at a lower voltage. This device is suitable for use in switching applications at frequencies up to 5 kHz. Figure 5 shows a L293D IC which instructs the stepper motors.

![Figure 5. L293D Motor Drive IC](image1)

The servo motor is most commonly used for high technology devices in the industrial application like automation technology. It is an electrical device that rotates parts of a machine with high efficiency and great precision. The output shaft of this motor can be moved to a particular angle. Servo motors are mainly used in home electronics, toys, cars, airplanes, etc. Servo motors are classified into different types based on their application, such as AC, DC, brushless DC servo motor and linear servo motor etc. RC servo motor is the most common type of servo motor used in hobby applications, robotics due to their simplicity, affordability and reliability of control by microprocessors. Figure 6 shows a servo motor which is used for Z axis movement of the designing tool. Mini CNC Plotter machine is worked on input as G codes of design and converting it via use of software further transferring to Arduino, CNC Shield, stepper motors, servo motor. The set up has been worked on to maintain lowest possible cost. A simple construction of the 2D plotter has been designed. This is easier way to use stepper motor with pulleys and belts, CNC shield, stepper drivers, Arduino Board, etc. The Setup of machine is flexible that’s why it will be easily transported and Maintenance time is short. The basic flow diagram of CNC Plotter machine is shown in the above Figure 7.

![Figure 6. Servo Motor](image2)
3. Software implementation and Coding

To complete the task of the entire current work two software’s are used Inkscape and Processing. Inkscape is used to design the plotted image or text in this current work by using this software G-code file of a selected image or text is created. G-code is a commonly used numerical control programming language which includes X, Y, Z coordinates. G-code is a language in which people tell computerized machine tools how to make desire path. The G-code instructions provided to a machine controller (industrial computer) that tells the motors where to move, how fast to move, and what path to follow. The two most common situations are that, within a machine tool such as a lathe or mill, a cutting tool is moved according to these instructions through a tool path cutting away material to leave only the finished work piece and/or, an unfinished work piece is precisely positioned in any of up to three axis around the dimensions relative to a tool path and, either or both can move relative to each other. The same concept also extends to non cutting tools such as forming or burnishing tools, photo-plotting, additive methods such as 3D printing, and measuring instruments. The CNC plotter in this current work will work within 5cm×5cm (Width × Height). Initially the axes have been kept at the nearest end of the motors which is considered as origin to easily modify the design. Figure 8 depicts that an image of car is feed into the Inkscape software then it is converted into G-Code file. Then the G-Code is feed into the Arduino controller which instructs the motor shield and the synchronous movement of the two stepper motors and the servo motor the outer layout of the same car is plotted by the mini CNC plotter.

**Figure 7.** Flow diagram of design tool plotter

**Figure 8.** a) Input and b) plotted output image of a car
4. Results and Discussions

By using Mini CNC 2D plotter outer layout of any specific 2D image of different solid surfaces can be drawn easily.

![Figure 9. a) micrograph image b) plotted microstructural dual phase layout](image)

This paper presents an affordable low cost model of a CNC plotter machine which is able to draw different microstructural phase identification layout, automotive layout or any other solid surface using simple algorithm and available components. Here an outer layout of given scanned image will be printed, along with the image will also saved in different formats like .iges, .igs, .sat, .stp.

![Figure 10. Plotted Layout of automotive design](image)

Figure 9 is shown a microstructure of multiphase steel is provided into the Inkscape software. It converts the following image into G codes and feed it into the Arduino Nano microcontroller. Arduino instructs the stepper motor via L293D motor shield to move accordingly as per the provided G codes of the image. Finally due to the synchronize movement of two stepper motors and a servo motor a microstructural dual phase layout is plotted in the paper which can be further saved in different image format like .iges, .igs, .sat etc. and can be used for microstructural phase identification. Similarly different structural layout of automotive designs can be plotted effortlessly using this design tool plotter as shown in Figure 10. Figure 11 shows the Mini CNC plotter during working condition while sketching the architecture of the input image of a car. Following are the highlights of this work:

- It is aimed at students of multidiscipline engineering in professional degree and focuses on the hand on experience with the principles operations and practices of training professional, technical and multidiscipline engineers and those in related fields.
• This setup is the designing a low cost three axis Mini CNC Plotter using stepper motor, Arduino microcontroller and motor control software.
• The demand for Computer Numerical Control (CNC) plotter machines in Educational Institutions and Laboratories is rapidly rising with the advancement of automatic control system.
• Current investigation is presented an affordable model of a CNC plotter machine which is able to draw different circuit layouts on PCB, different microstructural phase identification layout for further FE analysis for multiphase steel, automotive layout and any other solid surface using simple algorithm and available components as a lab demonstration.

![Image of the CNC plotter machine during operation]

*Figure 11. During operation of mini CNC plotter*

5. Conclusion
This work is about building a mechanical prototype of a low cost CNC plotter machine which is able to draw a micro structural phase diagram layout, automotive designs, and any 2D image on a given solid surface. It consumes low power and works with significant accuracy due to precise controlling of stepper motors. This is a low cost set up as compared to other CNC product. It is made with easily available components and spare parts. It is designed for private manufacturing and small scale designing applications in educational institutes. The machine is designed with a very simple construction scheme and can be carried anywhere without much effort. The algorithm used is simple and can be easily modified as per the user requirement. The design tool can be replaced with a pinhead or laser head or any other cutting tool for different purpose of use. Software that has been used is open source, user-friendly and can be modified further.
References

[1] Joshi H, Khole K and Kulkarni N, 2018 IOSR-JMCE 6.44
[2] Pabolu VK and Srinivas KNH 2010 Int. J. of Comp. Sci. and Eng. 2(8) 2567
[3] Park HK, Kim SS, Park JM, Cho T. Y and Hong D.2001 In ISIE. IEEE Int. Symp. on Ind Electron Proc (Cat. No. 01TH8570) 3 1996
[4] Madekar KJ, Nanaware KR, Phadtare PR and Mane VS 2016 Int. Res. J. Eng. Techn.(IRJET) 3(2) 1107
[5] Jeon JW, and Ha YY 2000 IEEE Trans. Ind. Electron 47(1) 133