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Using Arduino as a Medium to Learn Computer Aided Manufacturing for Students

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Abstract: This project consists of the fabrication and development of an CNC plotting system which is able to move in all three axes (x, y and z). Arduino Uno R3 has been used with an Adafruit motor shield V1 for L293D stepper motor drivers, and microcontroller software to plot/draw any image and/or text in this project. The program we use converts the drawing data into G-Codes and M-Codes, which the microcontroller then executes. This project aims to learn about CNC machines and the G-Codes and M-Codes that are used to operate them. This low-cost project can also be used to build skills and provide students from diverse academic backgrounds with hands-on CNC machine experience.

Keywords: CNC plotter, G-code, M-code, Arduino Uno R3, Adafruit motor shield V1.

I. INTRODUCTION

A very advanced automated system known as Computer Numerical Control is frequently used as an aid to control the kinematics of machine tools. Increased efficiency, flexibility, and low manufacturing costs are among the advantages, as are decreased working time and production loss[1-3].

Controlling the machine's functions requires specific codes and numbers. Then one by one commands are used to control the machine and to design a component with accurate dimensions. These instructions are then converted into electrical signals, which are sent to the motors that drive the machine and execute the motions as feedback. The right-hand coordinate system determines the tool's motion.

To create two-dimensional plots, plotters are widely used. A plotter uses a pen to trace curves on paper and makes vector graphics drawings. The pen on this CNC plotter machine can be replaced with a laser source, and it can cut a wide range of materials with different strengths.

This project makes use of the Arduino Uno R3 microcontroller and L293D motor drivers. Arduino is capable of processing logical instructions when communicating with a program. The CNC framework is programmed using G-code scripting. G-code instructions are sent to a machine controller (in this case, the Arduino) that tells the motors where to go, how fast to go, and what path to take. The Arduino method simplifies the 2D plotter's microcontroller's circuitry[4-6]. With this project, one can learn about CAM concepts like 3 axis motion, G-code, M-code, and more. This project will also help with the Skill India initiative[7].

II. LITERATURE REVIEW

"Development of low-cost 3-Axis Arduino powered CNC plotter machines" has been the subject of a lot of research.

" *Puja Girhe, Shubham Yenkar, Arpita Chirde Feb 2018* " [8].
Their specification is for a mini CNC computer that can automatically draw and drill PCBs. Since stepper motors are precisely controlled, it is low cost, low power, and works with high precision. They claim that their design can be used in private production as well as small-scale educational applications.

" *Md. Mahedi Hasan, Md. Rokonuzzaman Khan, Abu Tayab Noman, Humayun Rashid, Nawsher Ahmed, S.M. Taslim Reza Feb 2019* "[9].
They used a microcontroller to create a low-cost, compact CNC plotter computer. About the machine's imperfect precision, they say it can be used to draw complicated designs. According to them, in the future, it can be used by a bluetooth module from a distance, and it can also be used to build a system for sketching big pictures using a long length rod and stepper motors.

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" *Bikram Sarkar, Asif Iqbal Khan, Amit Kumar Rana, Sanjib Kundu December 2019:* "[10].
A CNC plotter machine which is fabricated at very inexpensive cost and can draw a microstructural diagram of various simple or complex designs, and any two dimensional picture. Their design requires low-power input and can perform with a very high level of precision. Their architecture is user-friendly and adaptable to the needs of the user.

III. COMPONENTS SPECIFICATIONS

1. Stepper motor

Stepper motor is a specific type of DC motor without brushes which is capable of fractionating a complete revolution into a number of equivalent phases known as steps. The core of these CNC machines is made up of stepper motors. To take control of the drawing pen so that objects can be sketched, x axis motion and y axis motion is necessary which can be achieved by using 2 separate stepper motors. They play an important role in controlling the kinematics of CNC machines and dimensioning of the workpiece.

Fig 1. Stepper Motor

2. Stepper driver

Stepper motor drivers are responsible for driving the stepper motors. Stepper motors have the ability to rotate non stop even without any kind of command system. They have inherent interpreters that permit a stepper motor to be worked with straightforward stage and course contributions, just as customizable current control and different stage goals. The two stepper motors in this venture are driven by two unique L293D drivers with the Adafruit motor shield V1 .

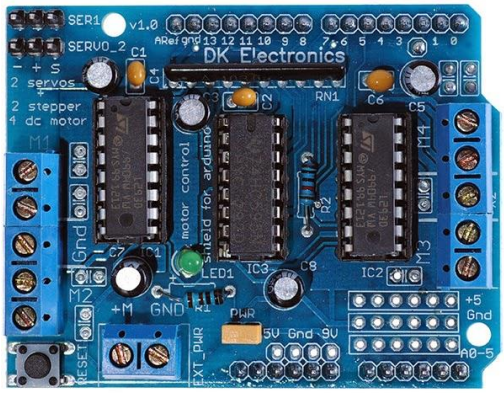

Fig 2. Adafruit Motor Shield V1

3. Servo Motor

In the direction of the z axis, the servo motor controls the up and down motion of the drawing pen. It is operated by transmitting a variable-width electrical pulse, known as Pulse Width Modulation (PWM), which can be accomplished with the help of a microcontroller.

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Fig 3. Servo Motor (Tower Pro SG 90)

4. Arduino

With the aid of program commands, the Arduino Uno R3 microcontroller, shown in figure 4 controls the motion of the stepper motors. This microcontroller is a user-friendly open-source platform that includes both hardware and software. The 14 digital input/output pins and the 6 analog input/output pins are easy to use on different kinds of circuit boards.

Fig 4. Arduino Uno R3

The board has a USB port for the connection between user and the microcontroller, it also consists of a separate slot for an external power supply. It works with the improvement of any control gadget by having a basic board that can be arranged and connected to the framework without the requirement for complex PCB engineering and execution. Since it is open-source equipment, anybody may acquire the determinations of its design and change or make their own.

Table 1. Specifications of Arduino Uno R3

Parameters	**Specifications**
Microcontroller	Atmega 328p
Input Voltage	7-12 VDC
Operating voltage	5 VDC
Digital I/O pins	14 pins
DC current per I/O pin	40 milliAmp
Clock Speed	16 Megahertz
Flash Memory	32 kilobytes
SRAM	2 kilobytes

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IV. ELECTRONIC SYSTEM AND CONNECTIONS

This portion will go through the electrical components and wiring that we used to develop and build our CNC plotter machine. Arduino Uno R3 and Adafruit motor shield with two L293D stepper drivers were used along with regulated input DC power, stepper motors, servo motor and electrical cables.
Figure 5 shows all the electrical components and wiring scheme. A USB cable is used to connect with the microcontroller.

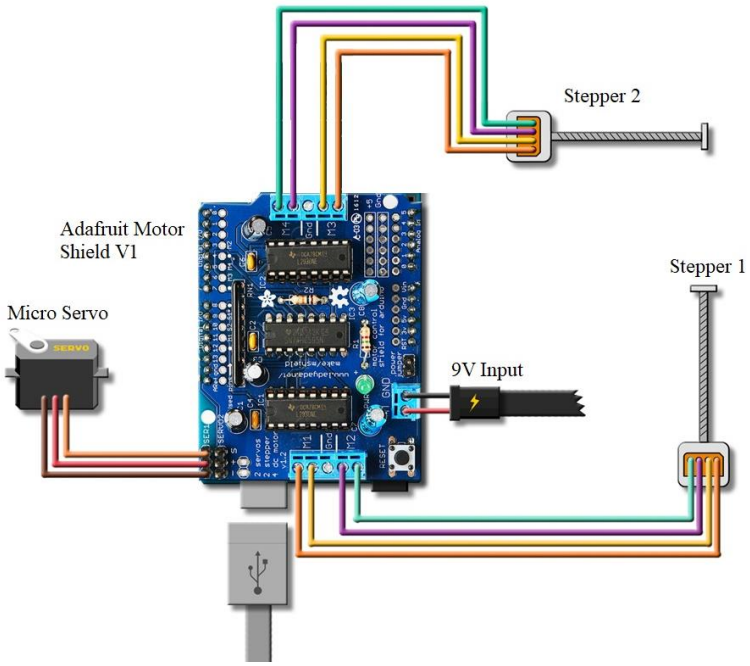

Fig 5. Electronic System and Connections

As seen in Figure 6, the electrical connections involve connecting the motor shield with the stepper motors and then positioning the shield above the microcontroller. The two stepper motors were driven by two separate drivers for the two axes.

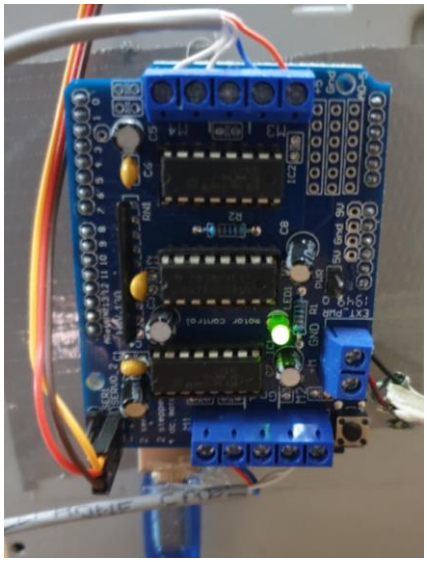

Fig 6. Arduino Uno R3 with Adafruit motor shield V1

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V. METHODOLOGY

1. Hardware

The two linear slides are driven by bipolar stepper motors to power the X and Y axes. We have used the Adafruit motor shield V1 to power the two stepper motors in the X and Y axes, which can drive two stepper motors or four DC motors concurrently using two L293D ICs, totaling four H-bridges. We have used a 'Tower Pro SG 90' micro servo motor that is directly controlled by the Arduino to power the pen up/down movement.

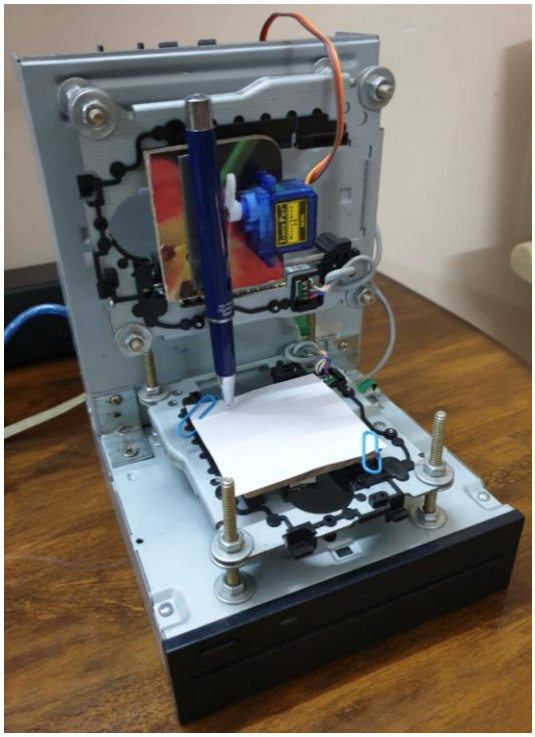

Fig 7. CNC Plotter

2. Software

Arduino IDE, Inkscape, and Processing are the three main softwares that are used in this project. To plot the picture or text it has to be designed in Inkscape first. The picture or text designed in this software generates a G-code. Various numerical control languages can be used to control the 3 axis motion of the plotter and one of them is G-code which is quite popular.

G-code is a programming language used to instruct computerized machine tools about how to follow a certain direction. The instructions given by the G-code informs an industrial computer that controls where the motors should be driven, how fast they should move, and which path they should take. In this project, Processing software has been used to stream the G-code to the Arduino. In this project, a 5cm × 5cm range is used to keep the cost down.

The nearest end of the motors were used to hold the axes at first, which served as an origin for quickly changing the arrangement. The cartoon character is imported into Inkscape and then compiled to a G-Code format. Arduino Uno R3, that connects both the stepper motors through the motor shield as well as the servo motor simultaneously, understands the instructions sent by the G-code. In this project, for an example, we have plotted a very popular cartoon character as shown in figure 10.

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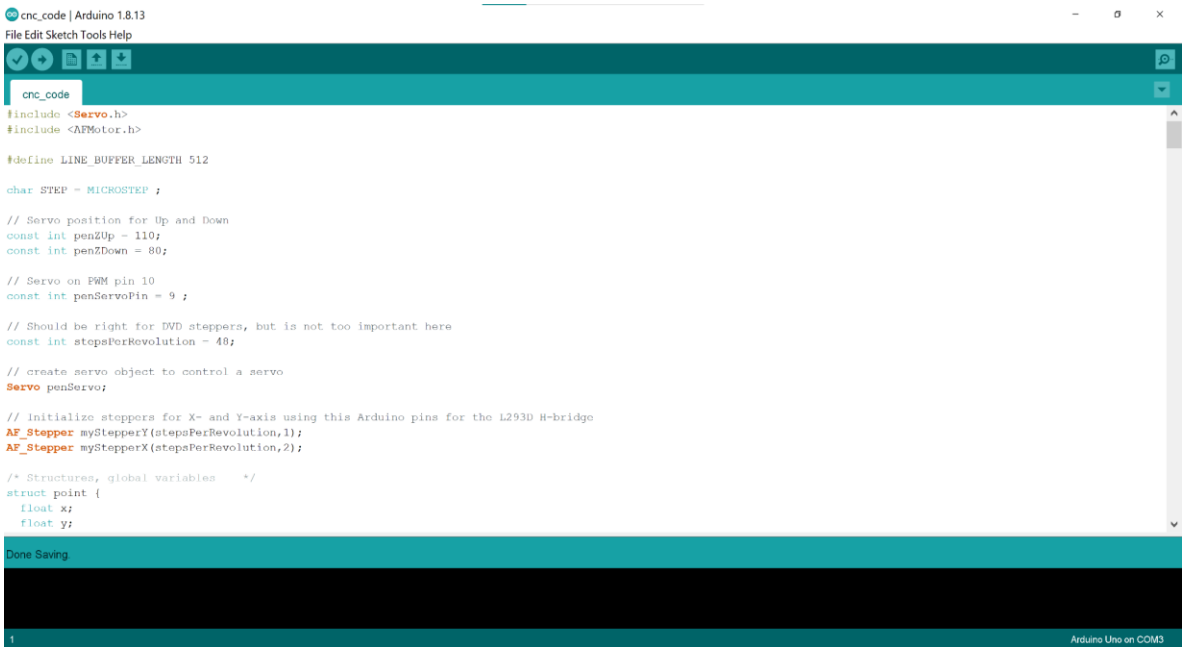

Fig 8. Arduino IDE

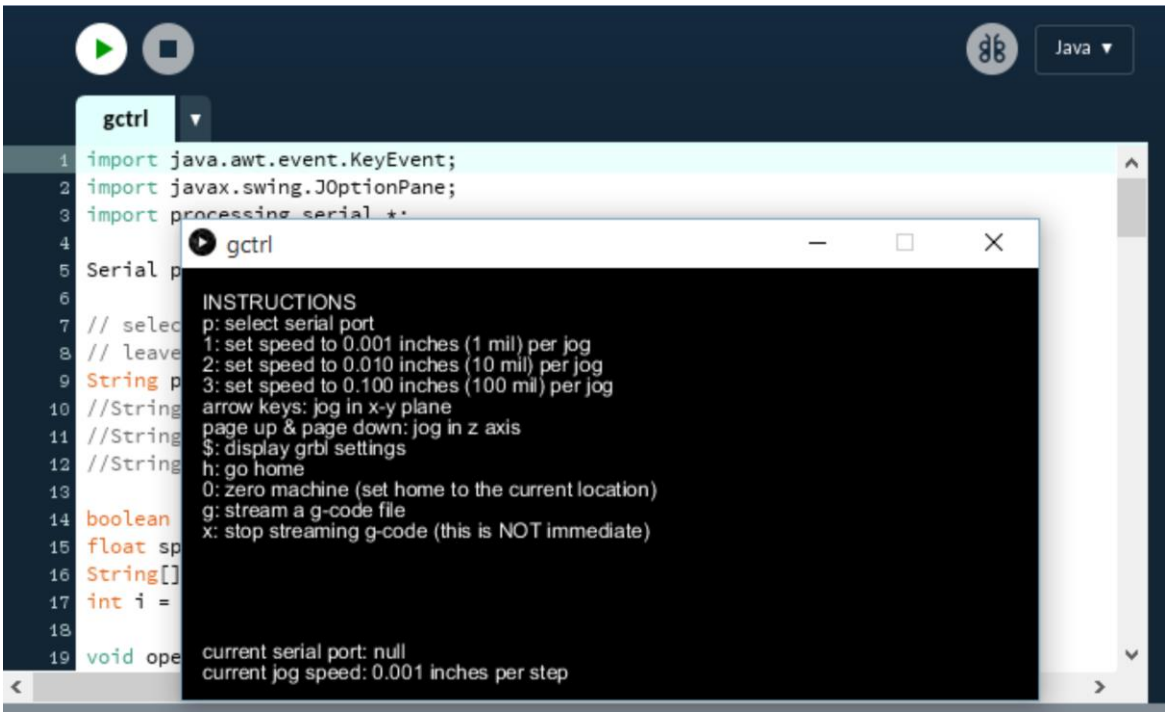

Fig 9. G-code sent by the Processing software

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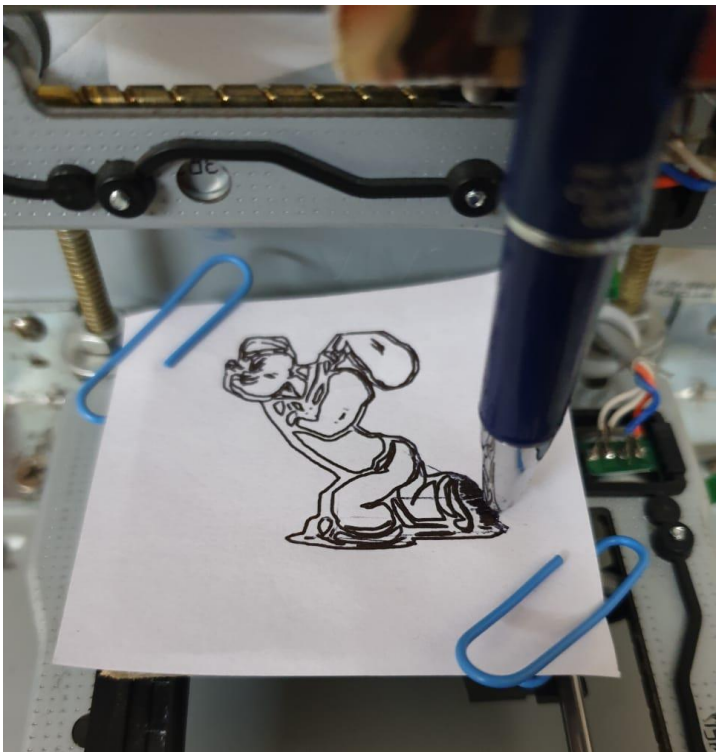

Fig 10. CNC plotter plotting the character

VI. CONCLUSIONS

We were motivated to do this project because we want to create a CNC plotter machine that is capable of drawing diagrams, vehicle designs, and every other 2D image. It has a low consumption of power and ability to function with great precision thanks to the direct operation of stepper motors. In comparison to other CNC devices, this is a low-cost setup. It's made of readily available parts and materials. It may be used in educational institutes for private production and small-scale design applications. The unit has a very straightforward fabrication scheme and can be taken about with little effort. The algorithm is straightforward and can be conveniently tweaked to meet the needs of every user.

Students can study different concepts of Computer Aided Manufacturing by using the techniques used in this project, such as coding a microcontroller, electrical wiring, parts assembly, and how they operate. With this project, one can learn about CAM concepts like 3 axis motion, G-code, M-code, and more. This project will also help with the Skill India initiative.

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