An ARM Based CNC Plotter

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Abstract: Computer numeric control (CNC) is capable of controlling the operation and motion of machine tools. CNC have found their applications mainly in lathes, drills, milling machines etc. Now a days the demand for CNC machines in laboratories and educational institutions have gained much recognition. Goal of this project is to form an efficient and low cost hardware architecture which is able to draw a circuit layout or an image on PCB or any other solid surface using simple algorithm. In this CNC machine, the entire movement control is coordinated by an ARM Cortex M3 based microcontroller, LPC 1769 with software implemented on LPCXpresso using embedded C. The microcontroller converts G-code into a set of machine language instruction to be sent to the motor driver of the CNC plotter. Processing is implemented here in order to provide a user interface.

Keywords: - Computer numerical control, Plotter, G-Code, ARM LPC 1769, Printed circuit board.

I. INTRODUCTION

In recent years, the technique of CNC has been widely used in the field of automatic control of the functions and motions of a machine tool. In early times Canon boring machine or Lathe was invented to do operations like shaping, cutting etc. But it was very time consuming because it does only one work at a time. CNC machines were invented to scale down the workload and it also includes advantages like high efficiency, flexibility and production rate. CNC machines are more precise than manual machining, and it can be repeatedly used in the same manner many times.

CNC Plotter accelerates the speed of large drawing by providing uninterrupted, quality and affordable cost. This CNC plotter is a 3 dimension controlled 2D plotting machine which uses a pen to draw an image or text on given solid surface. The 3 dimension controlled plotting machine can be used for different purposes like PCB design, logo design etc. A plotter for PCB design has gained much interest in recent days. This has geared up the demand of plotter in laboratories providing affordable cost and less complex design.

The proposed system mainly includes three steps which are collecting data, translating data and appropriate control action [1]. The movement of machine tool is controlled by a special program called G-code which includes letters and numbers. This is to be converted into electrical signal that is given as the input to motors that control the machine action.

Here the CNC machine is controlled through a PC. So it is possible for the user to design a text or image on-screen, and convert it to G-code (CNC-readable code) using software in PC. The G-code is then sent to the CNC machine for producing a physical copy of the text or image designed.

CNC pen plotters will be able to plot by moving a pen or other writing device across the surface of a piece of paper or any solid surface. The CNC 2-dimension plotter machine has a two axis control and a special mechanism is used raise and lower the pen.

II. METHODOLOGY

First the user needs to convert the input image or text file to a coded language called G-Code via Inkscape software within the PC. Then it is fed to the ARM microcontroller using FT232 module. As per the G-code microcontroller generates the necessary control signal for the mechanical subsystem.

Three-dimension controlling of CNC machine is done by using three motors in X, Y and Z axis. Figure 1 shows the block diagram of CNC plotter. Drawing area will be the XY plane, in which the positioning is accomplished by the help of two stepper motors. Positioning of the pen, that is the up (logic 0) and down (logic 1) movement is achieved by a servo motor on the Z axis which is controlled by the PWM pin of the microcontroller.
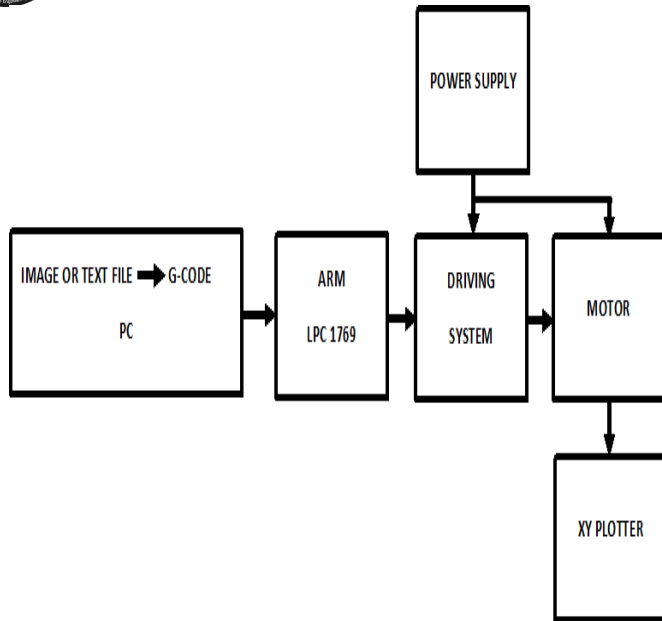
Fig. 1.Block diagram of proposed system

User interface is implemented using Processing software. There by various types of text or data can be plotted by controlling data from PC. When the Processing software send command to ARM it will start plotting the created G-code. Bresenham's Line Algorithm is used for plotting linear and circular path. Diagonal lines are approximated with unit steps.

For a two dimensional motion, it is suggested to use belts for the movement due to their fast process but here the system uses lead screw which provides comparatively slow movement but with better precision and load holding capacity. So even the plotting process took time, output will be finished in nature.

III. SOFTWARE

Mainly three software is used to complete the entire project work.

3.1 Inkscape 0.48.5

Inkscape is used to design the plotted text, image or diagram. By using this software G-code file of a particular text or image is created. G-code is a commonly used numerical control programming language which includes X, Y, Z coordinates. This numerical control program language includes numbers and letters.

Creating G-Code File Using Inkscape

In this project CNC plotter will work within 20cm×20cm area. So we need to choose the document properties of the Inkscape to adjust the working area of CNC plotter that is 20cmx20cm (Width×Height).
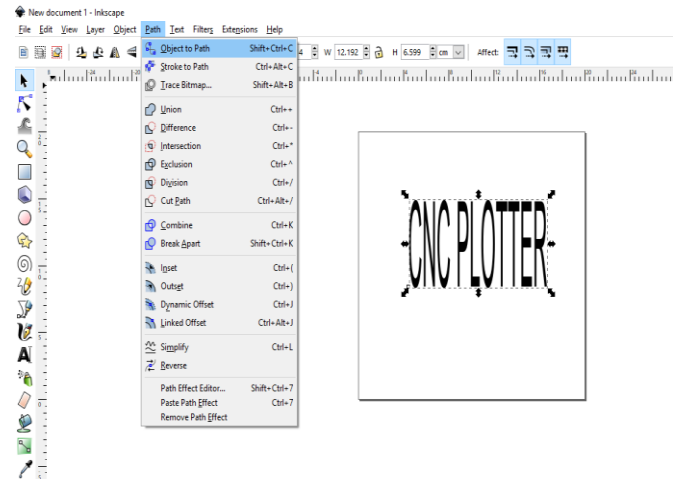

Fig.2.Conversion of text to G-code

In Fig. 2 the working area of CNC plotter is shown with the text written in the 20cm×20cm area. The text is selected using cursor and then select "object to path" from the drop down window to save the G-code form of the selected text.

G-code creation of an image is also possible with Inkscape software. In this case, the image file must have a transparent background. The image should be dragged into the selected area (20cm×20cm) then select "trace bitmap" from drop down window to create a transparent image and "Edge detection" is selected to create black & white image. After adding this transparent image in the predefined area "object to path" command is used to create the G-code file of the selected image by following the steps described earlier.
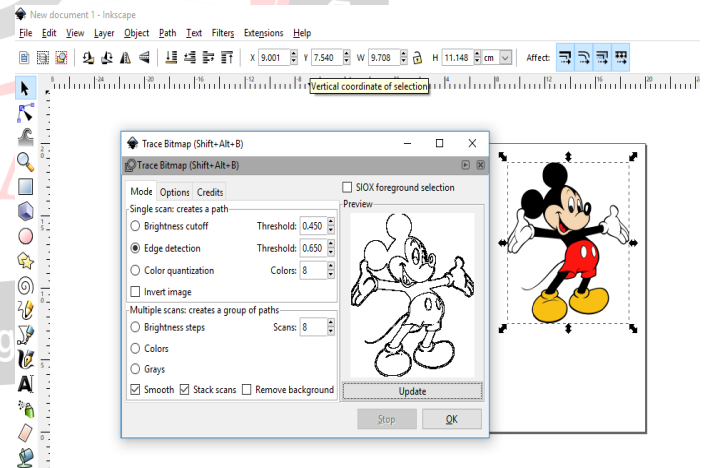

Fig.3.Creating transparent image from original image

Any image(formats) can be converted to machine code using Inkscape. GCODE formats are generated by adding Inkscape with necessary extension files such as 'makerbot unicorn gcode'.

3.2 Processing 3.3.6

Processing is a simple and flexible user interface programming environment. This open source programming language software is mainly used for electronic drawing. Processing has evolved into the design and modelling tool used for large-scale, motion graphics, installation work and

complex data drawing and visualization. It uses simplified graphical user interface and syntax and the processing language builds on the Java language.

This user interface was created to give the G-code to the microcontroller. UART interfacing is used for it. The generated G-code file from Inkscape is transmitted to the microcontroller line by line. After receiving each line of G-code file an acknowledgment signal is given from microcontroller to the processing software then only the next line will be send.

The Fig. 4 shows the user interface of processing 3.3.6 software after running program.
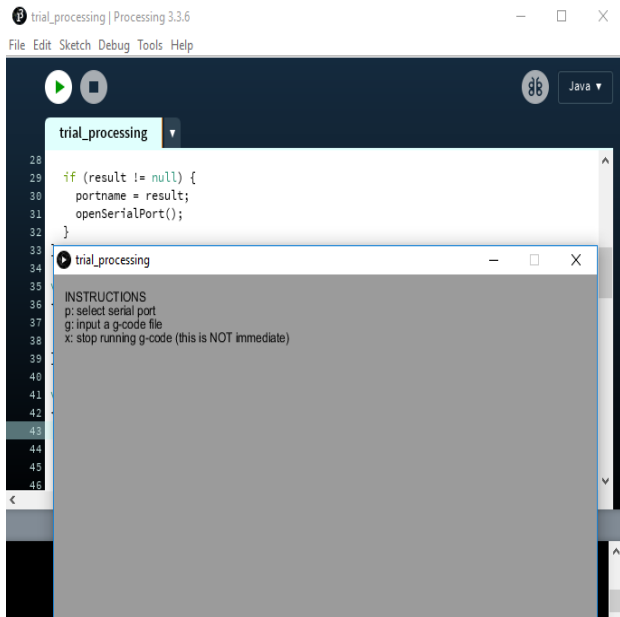

Fig.4.Processing window

Three options are provided for the user interface through a computer keyboard. The port of UART is selected by pressing "P". "G" character is used to upload our desired G-code file. Immediately CNC machine will start sketching selected G-code file of a text or image. "X" button will stop running G-code and stop sketching.

3.3 LPCXpresso 7.3.0

LPCXpresso IDE is NXP's low-cost microcontroller (MCU) development platform ecosystem, which provides an end-to-end solution and enabling engineers to develop different embedded applications from initial stage to final production.This is a complete embedded C/C++ integrated development platform.

These boards mainly used for point for LPC Cortex-M MCU based projects, provide easy-to-use and practical development hardware. A Workspace is created which is simply a directory that is used to store the project. Multiple projects can save in a single workspace, and can have multiple workspaces on a computer. Only single workspace can access at a time through the LPCXpresso IDE, although it is possible to run multiple instances in parallel with each instance accessing a different workspace.

IV. ALGORITHM

A simple line algorithm called Bresenham's Line Algorithm is used for drawing lines using this CNC plotter. For drawing lines first consider a line with initial point (x1, y1) and ending point (x2, y2) in device space. If dx = x2 −x1 and dy = y2 − y1. And we define the *driving axis* (*DA*) to be the x-axis if |dx| >|dy|, and the y-axis if |dy| > |dx|. Driving axis is used as the "axis of control" for the algorithm and is the axis of maximum movement. Within the main loop of the algorithm, the coordinate corresponding to the driving axis is incremented by one unit. The coordinate corresponding to the other axis (usually denoted the passive axis or PA) is only incremented when it is needed.Fig.5 shows the flow chart describing the algorithm.
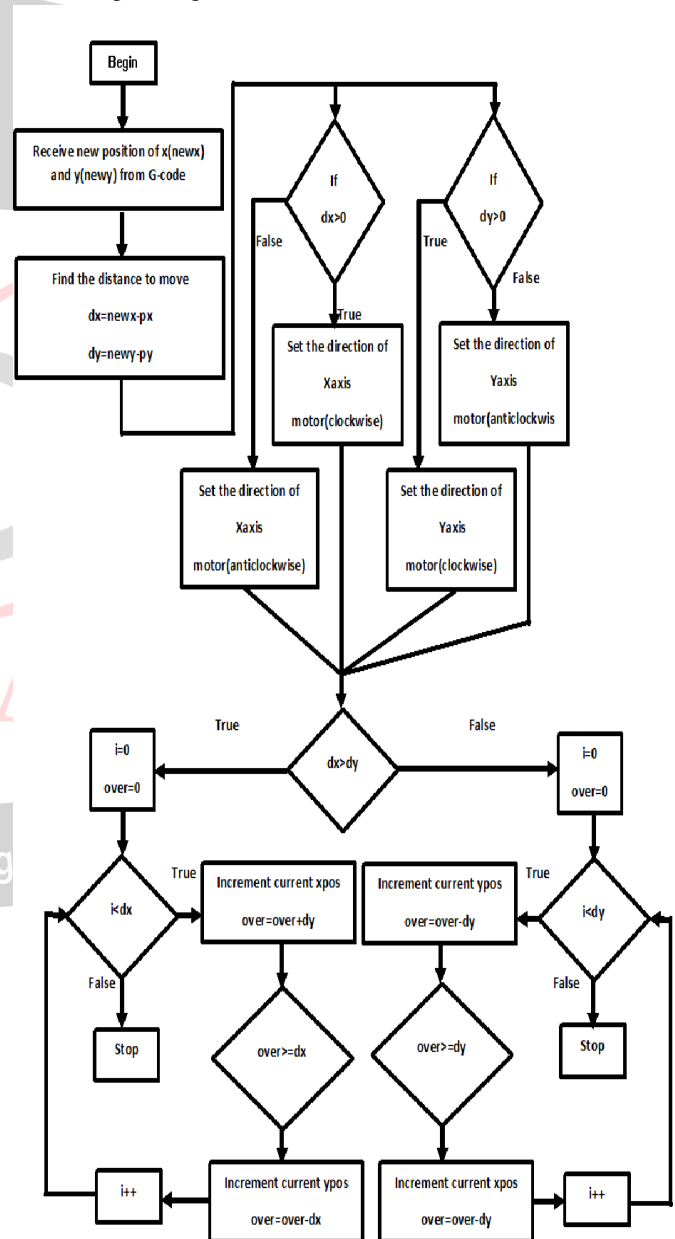

Fig.5. Flowchart of line drawing algorithm

HARDWARE IMPLEMENTATION

Stepper motors are used for horizontal and vertical movement and servo motor is used for the pen control (up and down movement). This arrangement helps to utilize the entire area. Control signals for the proper movement of the motor were given by LPC1769.

T-Slot aluminum extrusions are connected together to form the frame. Linear motion is achieved with the help of lead screw connected to motor shaft through coupler. Motor base is constructed using acrylic sheet and 3D printed parts.
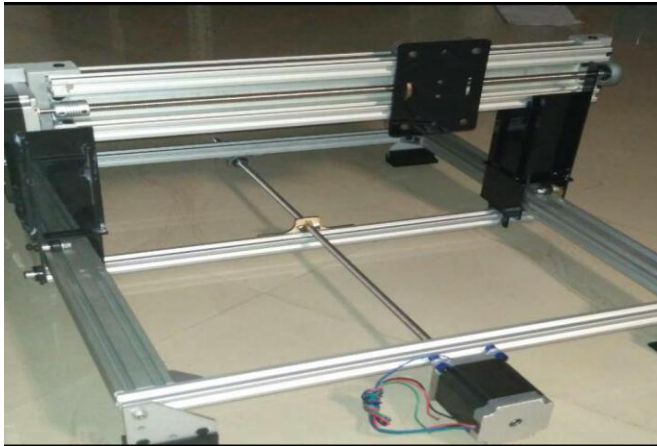

Fig.6. Mounted horizontal axis on vertical axis

The pen is mounted with the horizontal axis and it remains perfectly perpendicular with the horizontal axis during operation. The plotting pen is connected in a moving gantry plate.
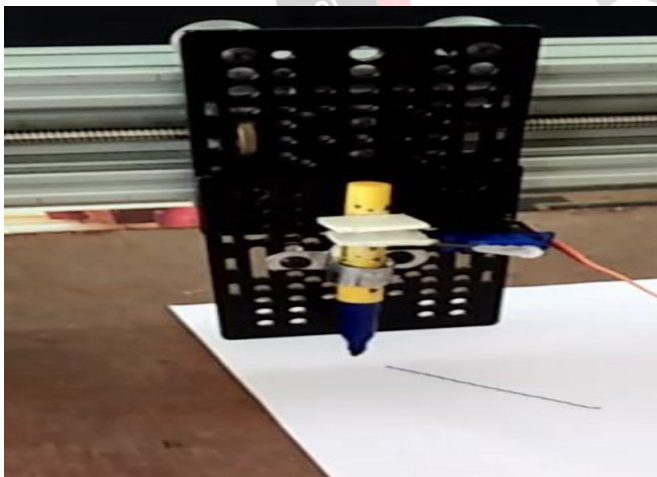

Fig. 7. Mounted pen with horizontal axis

V. EXPERIMENT RESULTS

Figure 8 shows the experimental arrangement used for plotting text as well as image on a solid surface.
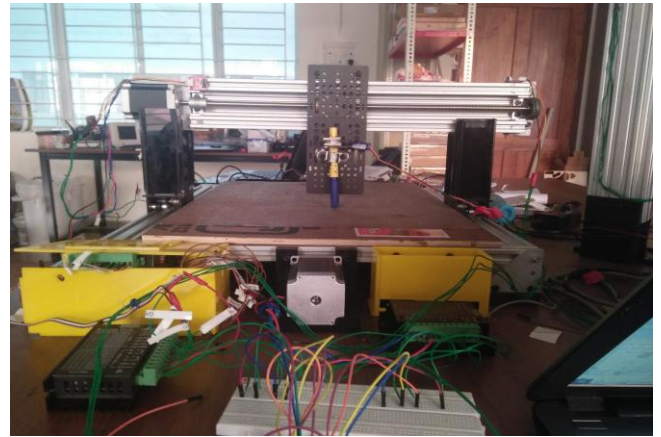

Fig. 8. CNC plotter

5.1 Plotting text file
The original file and the plotted files are shown in the Fig. 9(a) and (b).

(a)

(b)

Fig.9. Comparison of text file (a) original text (b) plotted text

Fig.10. Different font of same letter plotted using plotter

5.2 Plotting image file

Fig 11(a)shows the original black and white image and 11(b) shows the plotted image.
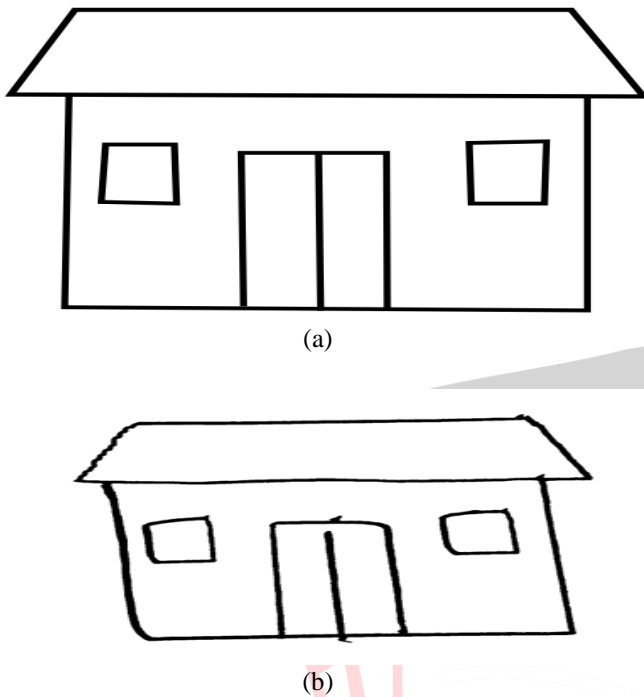

(a)

(b)

Fig.11. Comparison of image file (a) original image (b) plotted image

5.2 PCB layout

The Fig. 12(a) shows PCB layout that has been drawn on PC and Fig. 12(b) shows the one which is plotted by the plotter.
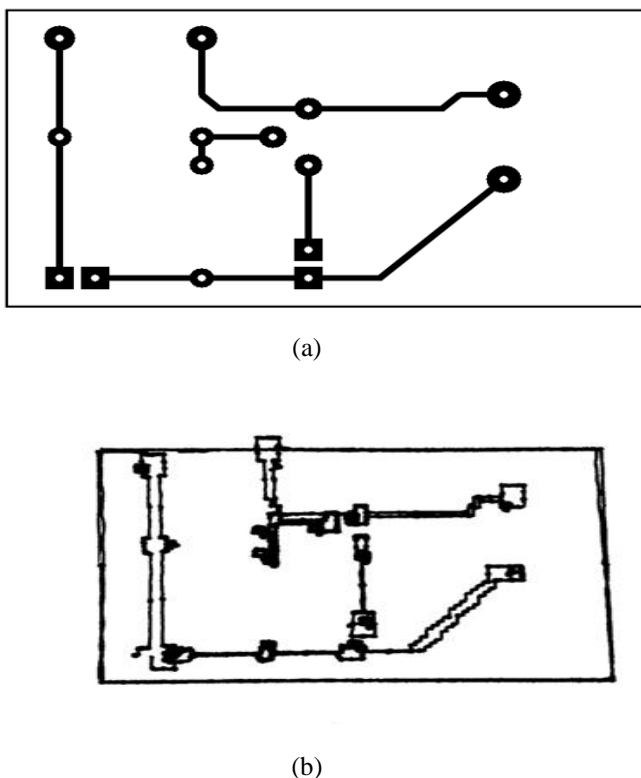

(a)

(b)

Fig.12. PCB layout by (a) inscape (b) plotter on copper clad

VI. CONCLUSION

Successfully developed a three dimension controlled 2D plotting machine finds its application in many fields especially in the field of graphics. Hardware and software were implemented to satisfy all criteria. The input image or text file can be drawn by taking inputs from PC. Electronic drawings like a circuit layout can be drawn to a PCB by using this plotter. Graphical user interface(GUI) can be integrated for making the system more accessible. In future the pen can be replaced with a powerful drill so that it can be used to plot blind scripts and for milling and drilling purpose. The servo can be replaced with a stepper motor and the pen with 3D pen to convert it to a 3D printer.

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