3D MOTION CONTROLLER FOR CNC ROUTER

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Abstract—**this article presents an overview of the 3D motion controller for CNC router. The basic purpose of a CNC machine is to accomplish accurate results as much as possible. As the title name indicates we have to develop a CNC machine which cuts an object in three dimensions namely X, Y and Z. This project mainly consists of three parts software, hardware and the mechanical part.**
A 3D object is designed in AUTOCAD which is saved as a (.DXF) file. A log file is created using MATLAB which consists of all entities of the three axis. Developing a G-code is a major aspect in software part. The hardware portion consists of controllers and drivers. The data transfer between a computer and a CNC machine tool is often accomplished through a serial communication port. International standards for serial communication are established so that information can be exchanged in an orderly manner. Major mechanical components in a CNC machine include spindle, screw rails, bolts, DC motor and a stepper motor. The mechanical machine works according to the numerical data which is being sent to it by the computer. The model is designed such as to cut an object in three directions. DC motor being powerful helps in drilling and cutting objects. Stepper motors on the other hand having controlled movements control the axis movement.

I INTRODUCTION

Wood working instruments have been used since ages. The first practical wood machine came into being in 1800 by Henry Maud slay. It was a simple machine which held the material in a clamp, spindle, and then rotated it in such a manner that the cutting tool carved it into the desired shape. Every movement was controlled by the operator and he had to repeat all the movements again and again for the same object he created. The first milling machine was created on the same pattern except that the cutting tool was placed in the rotating spindle. The material was placed on a worktable which was then placed under the cutting tool. The motions that are used in a machine are known as "axis". Most common are X (from left to right), Y (from front to back) and Z (from top to bottom) axis. One of the drawbacks of early machines was that they needed some kind of an operator to operate the machine every time. As it was tiring the number of same units to be created by an operator was limited. Even a slight difference in measurements resulted in a failed object. These errors also resulted in a waste of raw materials. With the passage of time and with limited number of natural resources there came requirement in technology which not only increased the production but also resulted in producing high quality products. Men power was reduced and computer aided software's such as CAM was introduced. Hundreds of same objects are now being produced with much accuracy and precision. Also time frame for creating objects has been drastically reduced [1].

II THEORY

A CNC machine is a machine which receives numerical data, interprets it and then moves it accordingly in a specified fashion. Following are the objectives of our project:

- To understand the working principle of CNC machines.

- To understand the applications of CNC machines.

- To understand the basic concepts of CAM software.

- To understand the characteristics of 3D objects.

- To understand the interfacing between CNC tool and Desktop PC.

- To be able to prepare CNC part programs for machining 3D objects.

- To understand the characteristics of drivers and controllers.

- To understand the basic principle of feedback devices.

- To understand the working principle of DC motors and Stepper motors [1].

III SOFTWARE

CNC Software provides ultimate handling over the machine operations in form of a GUI. Usually CNC Software uses following features to be included:

Machinist calculator

Quickly calculate speeds and feeds, bolt circle coordinates and much more. This feature is commonly used to handle the spindle's performance with respect to user choice.

File Upload/Download

Feature is used For Uploading and downloading the CNC Files

File Lookup

Is an application designed to quickly search through your CNC files using keywords contained in the files. An excellent help in managing that growing number of CNC programs!

Block number

Easy to use dialog boxes allow the user to quickly number or renumber the whole file, sections of the file, sub programs, etc.

Store code

Save often used segments of CNC code in an easy to use library

Switch axis

Convert files from vertical to horizontal machines; change the orientation of cuts by switching the values of coordinate addresses. E.g. X to Z, Z to X.

Shift coordinates

Add or subtract a specified amount from any or all coordinate values. Move machined features, or use in conjunction with copy/paste to duplicate parts, etc.

Syntax coloring

Helps improve readability of codes. Also colors common mistakes red (letter O instead of zero, for example).

Work envelope

Show the maximum positive and negative amount of movement for X, Y and Z axes. Covers the whole file, or between designated tool changes.

File compare

Graphically show the differences between two files. It is not the CNC-programmer's concern to design a drawing in AutoCAD software. In fact, this is the job of a CAD engineer to design the whole figure in efficient manners. The only concern of a cnc-programmer is to read the design, extract it's X, Y and Z coordinates and displays the same design in his own programming atmosphere. We used MATLAB to read AutoCAD design through DXF file.

IV INTRODUCTION TO MATLAB

MATLAB (matrix laboratory) is a numerical computing environment and fourth-generation programming language. Due to Its easy access to numerical computing we preferred MATLAB over Visual C language. The MATLAB application is built around the MATLAB language. The simplest way to execute MATLAB code is to type it in the Command Window, which is one of the elements of the MATLAB Desktop. When code is entered in the Command Window, MATLAB can be used as an interactive mathematical shell. Sequences of commands can be saved in a text file, typically using the MATLAB Editor, as a script or encapsulated into a function, extending the commands available.

V CNC CONTROLLER

CNC Controller is the hardware that makes CNC Software to interact with CNC Mechanical system. Controller drives the 3 stepper motors (each dedicated to different axis) in the way that software commands. We used stepper motor to drive the machine in 3 axis. Bipolar stepper contains four wires; its detail is discussed later on in mechanical chapter. To derive the motor a circuit is implemented with L297 and L298 deriving IC's. L297 is used to implement general logics such as half step/full step, clockwise/counter clockwise and enabling the motor etc. while L298 is used to generate the sequence that runs stepper motor [3].

VI MECHANICAL FUNCTIONING AND PARTS

The mechanical factors and mechanical parts required for CNC, probably the most difficult part of project. In order to make it simple and easy to understand we used the simplest and most easily available parts. To ensure the stability of machine and its optimum performance these parts are selected to work with motors easily in industrial environment. Mechanical system of machine covers from tiny nut and screw bolts to roller belts running over the shaft of the motor to rotate or float screw rails. Mechanical movement of router along the three axis over the object precisely and accurately depends on the accuracy of motors. As these motors are collectively responsible to move the router, that carve the object under it [2] [7].

From the drawing to the workpiece

1. Reading drawing
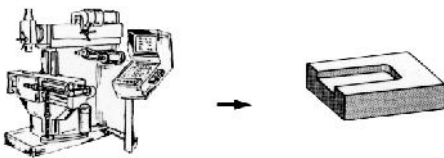
2. Programming
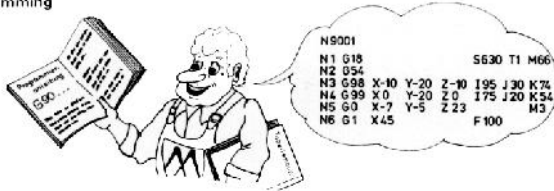
3. Inputting program

4. Manufacturing

Fig 1 Work piece

VII   FEATURES

Reading DXF File

We read DXF in matlab as a simple text file is read. Since, entities section contains the design properties related to drawing, our only concern is to read its entities section from top to bottom. Entities section is always changed for different kinds of shapes, and gives all information that we needed to design same object for the programming interface.

Amongst all the shapes handled in AutoCAD software, we covered following shapes in our project.

Line

In the line entity, starting and ending points of a line are mentioned. Following example is the representation of entities section when a single line is drawn using AutoCAD.

Line entities Section

```
ENTITIES                        // start of entities section
 0
```

```
LINE                            //start of line
 5
190
330
1F
100
AcDbEntity
 8
 0
100
AcDbLine                        //start of coordinates of line
 10
5.0                             //value of x1
 20
5.0                             //value of y1
 30
0.0                             //value of z1
11
15.0                            //value of x2
 21
10.0                            //value of y2
 31
0.0                             //value of z2
 0
ENDSEC                          //end of entities section
```

Circle

In circle entity, center point of circle and its radius are given.

```
ENTITIES
 0
CIRCLE
 5
189
330
1F
100
AcDbEntity
 8
 0
100
AcDbCircle
 10
10.04588306922326
 20
12.03700802362987
 30
0.0
 40
5.0
 0
```

Endsec

The software made for the CNC-Controller consists of numerous features that are included to provide user a friendly interface with machine. The software enables user to perform his cutting more efficiently. For example 3D-View of a design, Automatic Log file generation, Cursor options, spindle position, pause/resume option provides the user ultimate interface to perform the cutting. Apart from the fact that CNC-Machines are always designed to derive the spindle automatically, we introduced a Manual control that enables user to create his own design without using any CAD software. Some of the features that we used in our software are given below.

Graphical User interface

Without the GUI (graphical user interface), a software has no rights to be called a "Software". So, this is one of most important features that a programmer should add in his programming. GUI helps user to perform his tasks quickly and efficiently. It also gives software a better look [8]. Given below is the snap-shot of the GUI that we make for the CNC-Software. To open a design of AutoCAD, we need to open a .dxf file and show design is used to display the same design in white block. After that start machine button is used to start a machine.
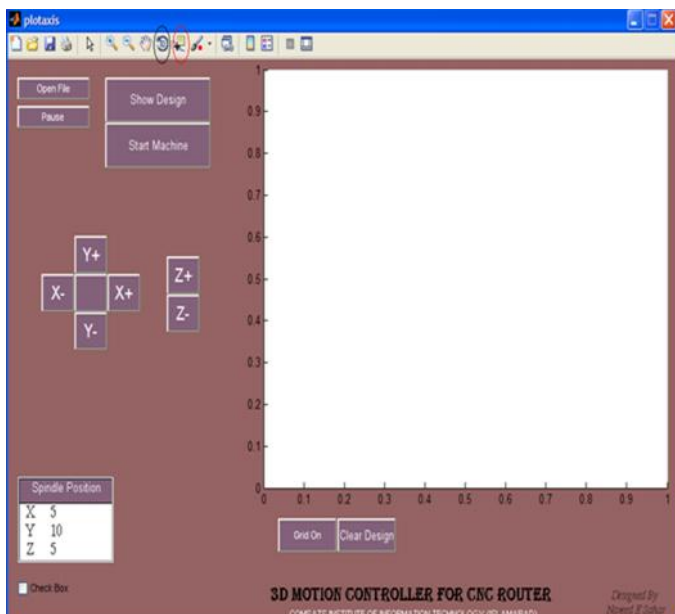

Fig. 2 GUI Look at the start

Rotate 3D

This feature is implemented to give user a permission to view the design from any angle. User can view the object from any dimension while it is being cut (real-time) with help of

3D-Rotator. Given below (figure 2) is the snap-shot taken after rotating a 3D-Cube, designed in AutoCAD. 3D-Rotator is shown in figure 1 black circled.

Data Cursor

Data cursor is used to view the x, y and z location of any point of design. Data cursor is also available in real time. In figure 2, data cursor is used to view the position of a particular point (x=5, y=5, z=5). Data cursor symbol is red circled in figure 1.

Spindle Position

This feature guides the user with current location of the cutting tool. As the machine runs, current x, y and z are shown in the bottom left corner of the graphical user interface.

Grid

User can on/off the grid according to his requirements. Grid is off in figure 1. While on in figure 2. This feature help user to locate the projections of the corners. This feature is also very helpful while manual control of machine.

Manual Keypad

A manual keypad is added to graphical user interface to manually control the position of the spindle. User can use this feature while automatic control of machine too. Manual keypad is created by toggle buttons to make its handling friendlier. Keypad is eligible to drive spindle in all three dimensions. Buttons X+, X-, Y+, Y-, Z+ and Z- are added to perform corresponding tasks

Pause/Resume

The option of pause and resuming is added to make eligible to take a break during cutting. User can use this option to have a break for a while and understand the design glitches
.
Log File

When we open a .dxf file, a log file is generated in text form. This file holds the information about all the points, the spindle passes through. Later on log file can be used to extract all points of the design. A log file generated by a simple line from (5, 5, 0) to (15, 5, 0) is given below in figure 3. First row gives x-values, second y-values and third row gives z-values of the design.

L298 driving IC is used to generate the sequence that require to run the stepper motor. The IC is also known as Dual Full Bridge Driver. It generates the following output signal in case of clock wise driven motor [5] [6].

VIII HARDWARE

Fig 3 L297

A. L297 IC

Four phase stepper motor is driven by L297 stepper motor controller IC. It enables the user to derive the motor half step/full step and wave drive modes. Following diagram shows the detailed connections available on L297 IC.
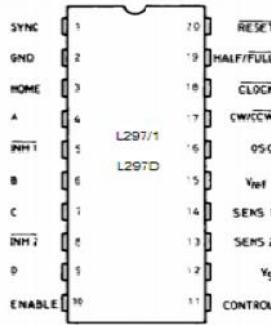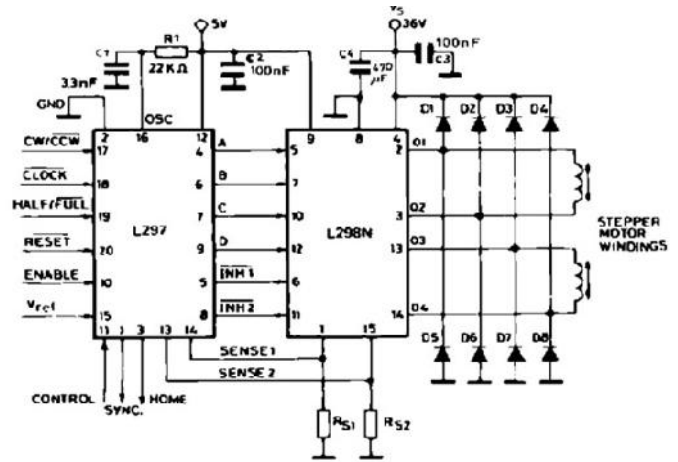

Fig 4 (L297 Configuration)

The L297 is used with a quad Darlington array, dual bridge driver or discrete power devices in step motor driving features. It receives clock step, direction and signal mode from the controller system and generates control signals for the power stage. Following table shows the each pin connection with its corresponding task [6-11].

B. L298 IC

.

Fig 3 L298

Fig 6 Two phase bipolar stepper motor control circuit

IX CODING

Function to read and arc

While programming the function that reads an arc from entities section, central coordinates or x, y and z are passed to my arc in form of a, b and c respectively. Furthermore a starting and ending angle of arc are also passed to that function.

XI CONCLUSION

As we are working on 3d CNC machine the first thing is to understand the function of a machine and router movement on three axes that is along x-axis, y-axis and z-axis for our consideration. For the purpose of its movement along 3 axis we use three stepper motors which moves the router along the respective three axis obviously for cutting down the object. Each motor shaft is connected to respective screw rail through roller belt.

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