

Development of Arduino based Omni Wheel Plotter



Karthik N, Abhijeeth Nagaraj, Sadanand V Giraddi, SuryaShankar Bhat B, Arjun E L

Abstract: This project demonstrates and tests the feasibility of an omni wheel plotter, where plotters are used to obtain the vector and line drawings of engineering models. The plotters developed before were having rigid frame, bulky and many of the plotters developed for academic purpose are for research purpose having less flexibility or constrained to a large extent. In this project, a plotter is developed which does not contain any rigid frame. Instead it uses a movable frame with omni wheels attached to it for mobility. The use of omni wheels makes the design of chassis or frame easy. To further simplify the design, a pivot joint suspension is built into it. The electronics part of the plotter consists of an Arduino Uno microcontroller board, ULN2003 stepper motor driver and a PCB to provide the power for running the motor drivers. The 'G' and 'M' codes are used to plot the required figure by the plotter. All connections were first designed and tested on a software called Fritzing. For programming the 'Uno' microcontroller, software provided by Arduino is used. The codes are communicated to the plotter with the help of HC-05 Bluetooth module. For sending these commands, a software called Coolterm is used. All software's used for design, fabrication and coding of the electronics is based on open source license, while the chassis has been designed using SolidWorks software. These plotters can be used for plotting 2D figures and PCB circuits, they can also be used for cutting 2D shapes and removal of excess material by replacing the pen with suitable cutting tool or laser cutters.

Keywords: Servomotor, Omniwheels, 28-BYJ-48 stepper motor (12V), ULN2003 Driver, Arduino Uno, HC-05 Bluetooth module.

I. INTRODUCTION

Designing and drafting were always a part of a product's life-cycle. Previously, both these activities were done simultaneously by designers during design process. Later when computers were introduced, designing and drafting became separate entities i.e. first, the 3D models were developed using modelling software such as Catia, Solidworks, etc. These designs were later needed to be printed onto a sheet or paper for drafting. Conventional printers could not be used for drafting as these printers, those days were designed to print documents and less emphasis for complex shapes and pictures. For this reason, a plotter was needed.

A plotter uses a pen rather than a print-head to plot points, lines which could be connected to form polygons of different shapes onto paper. For printing vector graphics, a plotter was more advantageous. The contours of the 3D model could be easily replicated onto paper with accuracy and with ease. There are many types of plotters: pen plotters, electrostatic plotters, cutting plotters. Pen plotters: Pen plotters use a pen which draws lines and contours onto the paper. They are a bit complex in design as it uses many different colour pens for drawing different colour contours, also it is purely mechanical in nature. The drawings thus created took long time to finish the drawing.

Electrostatic plotters: They work on the principle of the Xerox machine, here, instead of a pen, electrostatic forces are used to bind the ink with the paper. But here, instead of a drum the paper is directly exposed to the electrodes or the charged ink particle is sprayed onto the paper. The resolution is determined by the number of nozzles per mm or inch.

Cutting plotters: In these plotters, a knife or cutter is used for cutting the paper or similar material such as vinyl or Mylar. Plotters now are slowly being replaced by inkjet printers that work almost like electrostatic plotters, but they are bulky and can be used at only a single place near a computer. Further, they are complex in design and although prices have come down, there are still some improvements needed. The ink is wet after the paper exits the printer and can cause smudges if handled without care. In this work, the plotter addresses the issue of flexibility i.e. it must be able to plot on any size of paper or drawing. It also is simple to design; cost is reduced due to this.

II. LITREATURE SURVEY

B LakshmiPraba et al. [1] developed a mini CNC plotter for PCB drawing. The plotter uses Arduino and ATMEGA 328 controller for plotting. More emphasis has been given to software. They have used open sourced software for reduction in cost. All circuit drawings have been converted to 'G' and 'M' codes by software called Inkscape. The plotter hence developed can draw PCBs of 20x20 to 30x30cm. The plotter is a cost-effective plotter and hence can be used in non-industrial setups such as institutions or small-scale industries or other private use. The pen in the plotter can be replaced with a pinhead or laser head or any other tool for the necessary process. Ion-Cornel Mituletu et al. [2] have developed a CNC pen plotter from reused computer part. They have used stepper motors from CD-ROM drives of computer for movement of pen head of plotter. The frame of plotter was also the hardware of the CD-ROM.

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The plotter had been tested for plotting text and images demonstrating its accuracy and precision. The plotter was developed from used parts; hence it is cost effective and efficient. They conclude that existing plotters are expensive, difficult to maintain and require highly skilled operators. But the plotter developed by them overcomes these drawbacks at reasonable levels of accuracy and precision because of static rigidity and positioning accuracy.

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M Anil Kumar et al. [4] have developed a mini CNC plotter for the purpose of sketching building drawings. They have used an ATMEGA 328 controller for accepting 'G' and 'M' codes and running the motors.

They have used stepper and servo motors from old parts of computers. The plotter has also capabilities for sketching PCBs. The model hence developed can accomplish the task of plotting building drawing through two methods, either by input of the 'G' and 'M' code or from the code generated by the software Inkscape.

Juraj Oravec et al. [5] have developed a mini CNC plotter for purely academic and research purpose. The main objective is to test automation capabilities for precise plotting in 2D space (like vector graphics) and illustrative extremum seeking for 2D functions using brightness maps and light sensors. Two microcontrollers- Arduino Uno and Nano have been used for controlling, two stepper motors and motor controllers. All components are mounted on light-weight, portable frame. The plotter hence developed is useful in visually and user-friendly imparting of academic concepts such as plotting of graphs and others. Further although simple in design, due to modular design, further developments will make the plotter more useful for other purposes also. Further, the use of simple components and open-sourced softwares make it easy to reproduce and build. Kajal J. Madekar et al. [6] have developed a CNC plotter with drilling capability for drawing and drilling PCBs. An ATMEGA 328 controller in an Arduino provided a PC interface between the plotter and computer. The plotter was programmed with help of 'G' and 'M' codes for motion. The ATMEGA 328 controller accepts the 'G' and 'M' codes while the Arduino controls the plotter. They conclude that the use of 'G' and 'M' codes reduces the workload on the processor and computer. Also, it makes easier to understand the working and following of the input code, at any point, any discrepancy can be identified and the plotting can be stopped.

T Shivakumar et al. [7] proposes the use of Python for the coding of plotter making it easier to code instead of G and M codes for CNC plotters. The current plotter developed with python code has about 0.8mm. This can be increased by using better mechanical arrangement and further, since the entire plotter was coded in python, it is easier to understand the working and the code can be tweaked to personalize the plotter further.

Joseph V Prisco et al. [8] have come up with simple dynamic, electromechanical model for gantry type and media feed using first principles and non-linear friction conditions. This was due to less precision in conventional gantry and media type plotters and cutters. Specifically, for cutting operations performed by such plotters/cutters.

Jimmy Linggarjati et al. [10] have created CNC plotter with interchangeable pen-head. The pen-head can mount an impact-engraver (i.e. pen) or a CO2 Laser for cutting

operations. The software used is all open sourced, the machine can be mass produced according to Indonesian standards. The precision of the CNC plotter is "what you see is what you get". As a result of this interchangeable head design which can mount up to 3 different tool heads, this plotter can be used in cottage or small-scale industries because of reduction in cost of production. This CNC machine can be attached with pen head, spindle head and laser head for different purposes.

Paulo Augusto Sherring da Rocha Junior et al. [11] have developed CNC plotter with view for future developments. They have in depth described the parts, processes involved in fabricating the plotter and how to operate with software and which software to be used for this purpose (LABview). This plotter has not been fully developed but all electronic systems have reached expected results and are ready to be implemented, but further testing was required for deciding the mechanical components, Aluminium 2011 was proposed to be used for its easy precision cutting.

III. PROPOSED SYSTEM

The plotter has two main circuits used. One circuit supplies the required amount of power to run the 28BYJ-48 stepper motors. This is accomplished with the use of a Printed Circuit Board (PCB) which is connected to the power adapter plugged to the wall socket and employs 7805 and 7812 voltage regulators to achieve a constant 12V DC output. The other circuit is the logic circuits between the microcontroller and other electronics components to control them. The microcontroller is capable to supply the required power to the servo motor and Bluetooth. The data signals are communicated from the Bluetooth, communicated to the 4 motor controllers and servo motor. The microcontroller was programmed using the Arduino IDE. These programs consist of data part and loop part. The Uno microcontroller was coded to understand and accept G codes from user computer. These codes were entered/communicated to the plotter through a Bluetooth module. This was done to achieve absolute independence between plotter and user. This was done to achieve absolute flexibility in plotter, if a cable was used for this the maximum plottable area would have been limited to the length of chord.

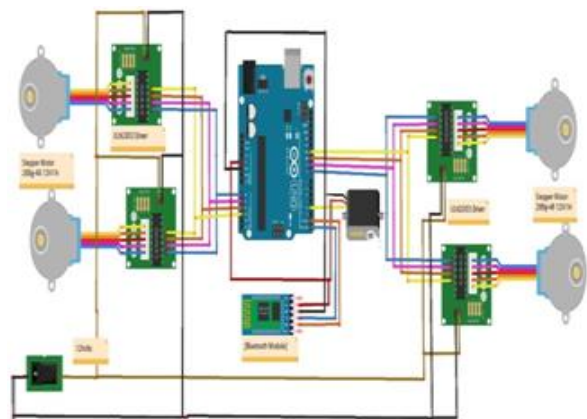


Fig.1: Design of proposed system of the omni wheel plotter in fritzing software.



IV. DESIGN AND IMPLEMENTATION

This Omni wheel plotter consists of three main sub-systems: Mechanical sub-system, Electronic sub-system, Software and programming sub-systems. The mechanical sub-system forms the chassis which supports all other sub-systems, also it provides motion to the entire model.

The electronic sub-system controls the mechanical components i.e. motors and pen lift.

It stores the program provided by the programmer and converts the electronic instructions to logical physical changes in the model.

The software and programming sub-system allows the user to input instructions in the English language (High level language) and converts it to machine understandable language (Low level language). The machine level language consists of high (1) and low (0) states i.e. true and false only.

A. Mechanical sub-system:

4.1. Chassis:

The Chassis supports all other components including motors and wheels. It absorbs some amount of vibrations from the wheels protecting the electronic components mounted on the top.

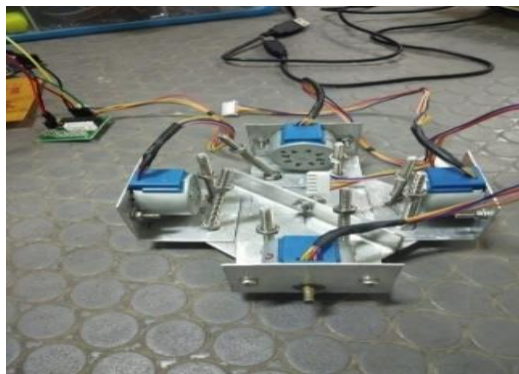


Fig.2: Bottom Part assembly of plotter.



Fig.3: Top Part assembly of plotter.



Fig.4: Final assembly Part of plotter.

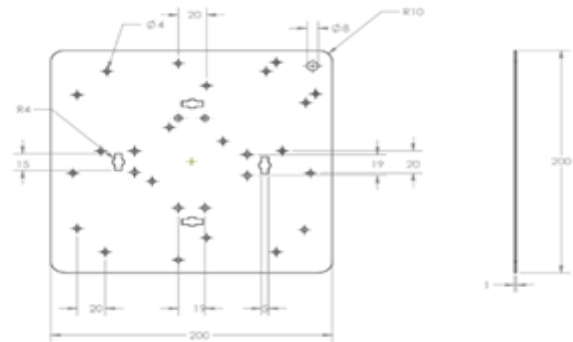


Fig.5: Part Drawing of the Top plate of the plotter.

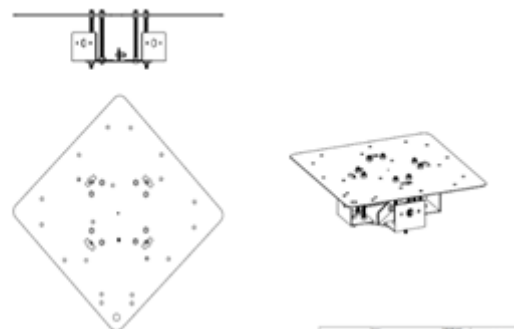


Fig.6: Final Part Drawing and assembly of chassis.

4.2. 28BYJ-48 Stepper motor:

Stepper motors are more useful for these sorts of applications because they allow the motor shaft to rotate in steps with definite angle between steps. This means better control over small distances requiring only partial motion of shaft. 28BYJ-48 stepper motor is relatively cheap, small in size and having 2500 steps/rev has an acceptable level of precision. Further it has a maximum speed of 500 rev/min which is sufficient for a plotter. This project uses four such motors to provide motion in 'X' and 'Y' direction.

4.3. SG90 Servo motor:

Unlike normal motors, servo motors can be programmed to rotate between two points with definite angle between them i.e. rotation is possible between two points only and any other point between them. Further they are small and light. The SG90 servo is used as pen lift for the plotter.



4.4. Omni wheel:

Omni wheels allow for movement in both longitudinal and lateral direction without much friction or slip. They consist of two normal wheels axis on the main wheel. This project does not employ feedback elements such as sensors and does not use vibration dampers for simplicity and weight reduction. Due to this, and the inherent bumpy characteristic of the wheel, the precision and accuracy reduces.

B. Electronic sub-system:

4.5. Printable circuit Board (PCB):

A PCB is produced by etching the extra copper off of a polymer base. It is used for providing a strong connection between all electronic components. This reduces the amount of wiring required to connect the different components and also saves a lot of space for other electronic parts like motor controllers.

4.6. Arduino Uno microcontroller:

Uno is a microcontroller from Arduino, a company that specializes in manufacture of different types of microcontrollers. As all microcontrollers, the Uno board accepts more instruction sets from user unlike microprocessors. The Uno is like the brain, it controls the motors through their controllers. It sends the signals required for actuation and movement.

It is connected to 4 ULN2003 motor controllers that actuate one of the 4 stepper motors.

4.7. ULN2003 Stepper motor controller

The ULN2003 motor controller is specifically designed for the 28BYJ-48 stepper motor. The output of the Uno board is not enough for running the motors. Hence these motor controllers are separately powered and connected to the Uno board. The external power supplies power to run the motors while the Uno board tells the controller when and which of the 4 motors are to be operated based on the input user program.

4.8. 7805 and 7812 voltage regulators:

7805 and 7812 are transistors that are used to obtain 5V and 12V stable and regulated DC power supply to the motor controllers to run the motors. Further, a 12V-2A rated power adapter is used for supplying the power.

4.9. HC-05 Bluetooth module:

The HC-05 Bluetooth module is used for wirelessly communicating with the plotter from the computer system which has the user program.

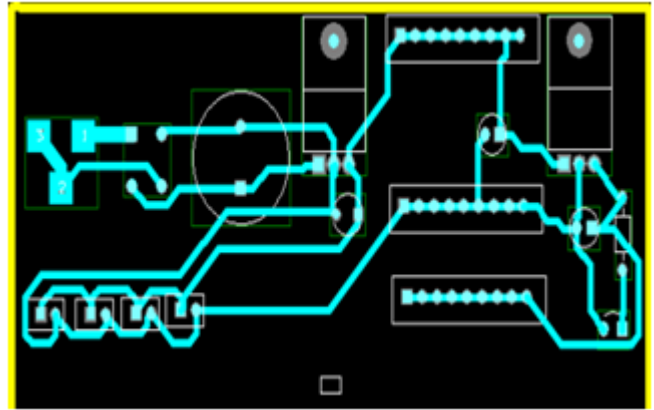


Fig.7: Design of PCB in Software.

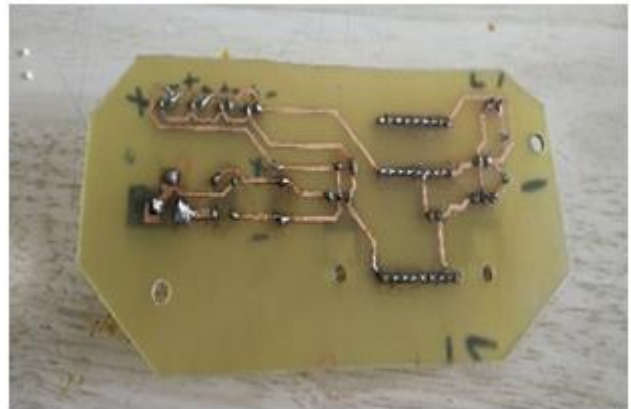


Fig.8: Fabricated Lower part of PCB.



Fig.9: Fabricated Upper part of PCB.

C. Software and Programming sub-system:

4.10. Arduino Programming:

The Arduino Uno is programmed using the software provided by them (Arduino). In this program, all the basic instructions and behavior of hardware is defined. Using a preinstalled library provided by Arduino, G-code and M-code can be input to be plotted.

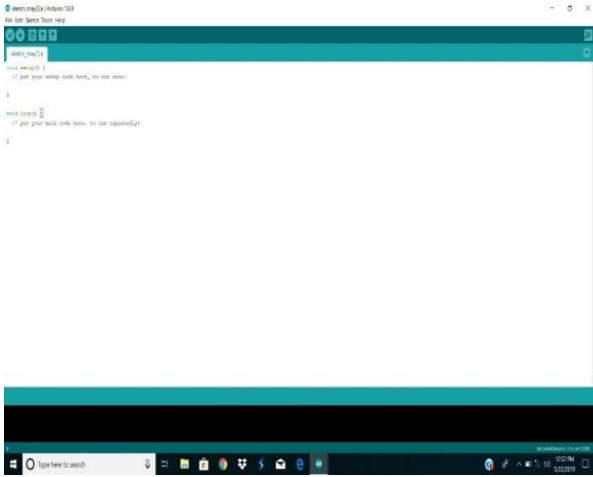


Fig.10: Arduino Uno software.

4.10. Cool term:

A software used to convert and communicate the G-code and M-code to the plotter from the user computer.

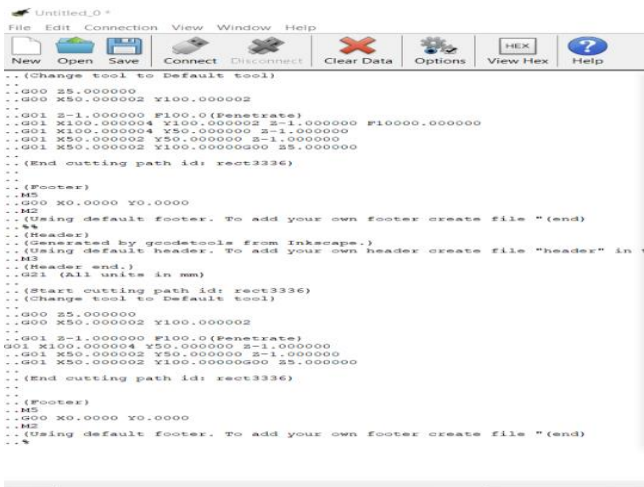


Fig.11: Cool term software.

V. RESULTS AND DISCUSSION

The plotter is unable to draw complicated shapes such as a rectangle with lines diverging from the centre. The lines do not end on the same position as expected but may have a variation of 1 or 2mm from expected position. The omni wheels of universal type are very useful for designing simple moving chassis for plotters. But due to their design, they do not allow the plotted contours to be 100% accurate, further they will not be able to handle major undulation in the surface they operate on. This can be overcome by the use of Meccanum type of omni wheels. These wheels do not cause vibration but only need a smooth surface to operate on. They are used commercially for applications such as motion of omnidirectional robots, but these wheels are more costly

than those of the universal type. The accuracy may also be affected by the weight distribution of the components on the plotter. This uneven weight distribution causes unwanted slip in wheels where there is less weight acting on the wheels. Since this plotter does not use feedback mechanisms, these slips will affect the resultant plotted contour producing uneven rectangles or squares.

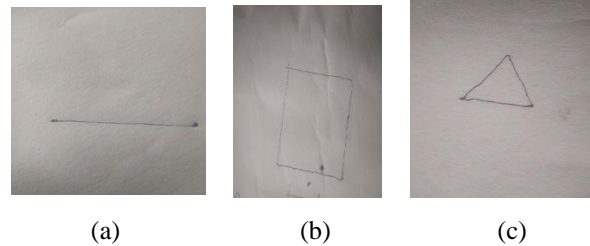


Fig.12(a) (b) (c) Drawings plotted by the plotter.

VI. CONCLUSION

The plotters were developed before having a fixed frame so the plotters were bulky and have to be placed on a table to work in this project the frame is not rigid and the plotter is compact hence suffer issues concerning accuracy and precision but further improvements in omni directional wheels, better design of the plotter and improvements in embedded electronics will definitely pave way for better plotters of this type.

FUTURE SCOPE

1. Adding extruder, it acts as 3D printer.
2. Precision and Accuracy can be increased.
3. Replacing the pen with laser cutting tool it acts as Laser cutting machine.
4. Replacing the pen with milling cutting tool it acts as 3D Milling machine.

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