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RESEARCH ARTICLE

Automatic Laser Engraving Machine for Different Materials based on Microcontroller

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Abstract In this article, we looked at how to go about creating a CNC pen or drawing machine of your own. Inkscape, which translates graphics and text into g- code format, was utilized as the controller for this project, with the microcontroller serving as the interface between the computer and the language of the CNC machine. The g-code transmits a series of x, y, and z coordinates to the motors; the servo motor controls the pen's movement in response to the Z coordinates; stepper motor 1 controls the rail's horizontal motion; and stepper motor 2 controls the rail's vertical motion in response to the X coordinate. The laser machine employs industrial applications to expedite manufacturing and perform engraving and cutting, resulting in a superior and expertly finished output. The carbon laser beam emitted by the laser engraving machine may be used for engraving, cutting, and shaping a wide variety of materials and end products.

Keywords: Microcontroller, CNC, sketching, computer numerical control, laser machine.

Introduction

CNC machine tools are the foundation of modern manufacturing because they eliminate the need for a highly trained labor force. Secondary schools, colleges, and industry groups all provide CNC training programs to equip their students with the necessary skills [1, 2]. You've undoubtedly seen skilled craftspeople carve wood by hand using a chainsaw and chisel. If you're more interested in the handmade variety of things, you've certainly seen metalworkers using manual lathes and milling machines to create a mechanical item that fits a specific specification. When this is the case, the artisans must manually manipulate the cutting instruments to get the required results [3]. It might take a lot of time, and the results might not be very precise [4]. In addition, a lot of practice is needed to get to the higher levels [5]. CNC stands for "computer numerically controlled," which describes the machinery used to make it (a machine that is digitally controlled using a computer). Its name denotes that its motions are controlled automatically by a computer rather than by a human operator. In the case of computer numerical control (CNC), we program the machine's movements by hand, line by line. The G-Code is the name given to this set of instructions. This software will have functions for moving the table (to which the workpiece is mounted), moving the cutting tool, rotating the cutting tool at a certain speed, and issuing supplementary instructions such as switching cutting tools and activating and deactivating cooling, suction, and clamping. All motors, controllers, and machine add-ons will get instructions from the software in the order specified by the designer [6-10]. Complex machine actions may be performed with a few simple keystrokes. Complex 3D models, for instance, may be generated using a ready-built application. In addition, the usage of CNC machine tools is crucial to the growth of small and medium-sized businesses. In order to close the gap between their financial resources and those of larger corporations, many small businesses are updating or reviving their older equipment with cheaper forms of CNC controllers. This study addresses issues in CNC operator training and shows how the open-architecture control system

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may be used in practice on a homemade 3-axis mini-CNC machine. The CNC machine tool described in this article is intended mainly for instructional purposes; it is inexpensive to build and requires just a single computer that is compatible with CNC software.

Therefore, the suggested mini-CNC machine may be a fully functioning element of an educational system [1] and avoids the issues that may arise from the need for additional equipment. Because of the ease with which the machine may be duplicated, universities can save money without having to purchase several copies for each student enrolled in a course [11, 12]. Due to the increased demand, many secondary schools and faculties have difficulty securing the necessary educational machinery.

Proposed Method

Despite their high price tag, CNC systems have become more commonplace in modern manufacturing because to the exponential development of technology. In an effort to bring CNC systems down in price and complexity, the concept of making a cheap CNC router was proposed. In this study, we explore the design and implementation of a cheap CNC router with the ability to do simultaneous interpolation on three axes. The savings come from combining a microcontroller-based CNC system with the conveniences of a regular PC interface. An offline G-Code parser is included, and the code is read and processed by the microcontroller via USB. New and improved methods are used in the system to manage a 3-axis CNC machine with little computing overhead and no drop in performance. The goal of making affordable CNC routers is to meet the growing demand from both small and big factories at a price that's both reasonable and competitive. The advent of cheap open-source hardware like the microcontroller is a huge step forward in computing. As a result of the abundance of pre-built software on the Internet that is compatible with open-source hardware, prototype and development times may be cut in half. Not only that, but there is a plethora of low-priced interfaces, sensors, and accessories to choose from. On the other hand, from the perspective of machine control, such tools may be perfectly appropriate for the creation of low-cost teaching models of CNC machines. In this study, we demonstrate the design and development of a prototype 3-axis CNC Router with a microcontroller-based control system.

1. If the program is created once, the same wrought object may be mass-produced with the same accuracy and identically.
2. High speed, high precision, and high efficiency.
3. Low cost and easily operable.

CNC Design

The machine's structure is its "muscular system." In doing so, it creates a unified system out of the many parts that make up the machine. Static and dynamic stiffness, as well as damping response, are all directly influenced by the machine structure, making it vital to the performance of the machine tools. With proper planning, a structure's stiffness may be maximized, leading to increased operational bandwidth and greater control. Since small-scale machine tools are often operated at greater speeds than standard large-scale machine tools, more stiffness is typically required. Our experimental setup is based on a Granty-style closed frame structure because it has the advantages of a strong ridged structural loop, symmetry, and high thermal stability, and is thus more rigid than the open frame structures often utilized for convenient access to the work zone. Most precision machines have closed frame designs. This makes it much simpler to relocate the tool in relation to a stationary work component. This building is much cheaper to construct due to its low material need. Because it is simple to move cutting tools along the Z-X axis, gantry designs are often used in machines meant to cut flat steel plate. The gantry's Z-axis forms part of the rail system it travels along. As for the Y axis, that's often formed by the gantry bridge itself. You can cut any form out of steel plate by motorizing each axis and coordinating the action of the two axes concurrently. In this way, CNC form cutting, which relies largely on a Z-X coordinate system, is well-suited to a gantry layout.

The Z-axis of a gantry cutting machine is supported by rails that may be attached to the floor, a pedestal, or even the edge of a table. The rails are built to withstand the weight of the machine and any attached devices while yet allowing for precise movements. These rails may be as basic as a metal strip, as complicated as a linear rail system with ball bearings that recycles its lubricant, or as massive as the rails of a railroad train, depending on the complexity and scale of the machine. A gantry cutting machine's X-axis will also be guided by a system, often one attached to the bridge. Since the X-axis rails only need to support the weight of a tiny carriage and cutting tool and not the whole gantry, they may be made smaller. Tool carriages on gantry machines may range from one to multiple. The X-axis motion of the tool carriages may be driven individually by their own motors, or it can be driven by a single motor with the tool carriages linked together by a steel band, tie rod, wire rope, or other mechanical device.

Ball/ lead Screws

In mechanical linear actuators, a ball screw is used to convert rotary motion into linear motion with little resistance [13]. Ball bearings, functioning as a precision screw, roll down a helical raceway provided by the threaded shaft [14]. Also, as can be shown in Figure 1, they can apply or endure large thrust loads with a negligible amount of internal friction.

Figure 1. Ball/lead screw (a ball screw uses ball bearings to eliminate the friction between the nut and screw and lead)

Ball Bearings

Ball bearings are a specific sort of rolling-element bearings in which balls are used to reliably and consistently keep the gap between the bearing races at a constant distance [15]. As can be seen in Figure 2, a ball bearing is designed to sustain radial and axial loads while simultaneously minimizing rotational friction [16-19].

Figure 2. Ball bearing (The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads)

Linear Rods

Linear rods are robust, rigid shafts made of Mild Steel that are used to sustain linear motion while also carrying the load [20]. Loads and support for linear movements in structures are carried and supported by linear rods equipped with a linear bearing assembly. The linear rod bearing assembly supports the whole weight of the structure, relieving pressure from the ball screw to provide linear motion with high precision and no wobble [21].

Linear Ball Bearings

The purpose of a linear bearing is to allow for linear motion. The linear bearing takes the strain off of the linear rods and allows for low-friction movement [22]. Bearings that allow motion in just one direction are called linear slides or linear motion bearings [23]. Bearings for linear motion come in a wide variety of designs. Typically, a rolling element bearing will have a sleeve-like outer ring and numerous rows of balls contained inside cages. Before being replaced by stampings, the cages were originally machined from solid metal. It moves easily, has little friction, is very stiff, and lasts a long time. They can be easily repaired or swapped out at little cost.

Shaft End Supports

Linear rods or shafts may be supported tightly and securely by using shaft supports [24]. As can be seen in Figure 3, shaft support blocks are used for end or intermittent support under mild loads and when little shaft deflection is of no significance.

Figure 3. Linear rail assembly (linear rods, linear bearings, end shafts)

Shaft Couplings

For the purpose of transferring power, two shafts may be coupled together using a Shaft Coupling [25]. Disconnecting shafts from a coupling while operation is uncommon. Some couplings, however, have a torque limit and may slide or detach if that limit is exceeded. Couplings are mostly used to connect two separate pieces of spinning machinery, as seen in Figure 4.

Figure 4. Shaft V. coupler

Stepper Motor

A stepper motor is a synchronous, brushless electric motor that rotates its shaft in discrete increments in response to digital pulses [26]. This allows the motor's position to be controlled to go to and hold at any of these discrete positions without the need for a feedback sensor (an open-loop controller). Specifically, the axis motion is being driven by a NEMA 23 stepper motor, which is a 2.3 x 2.3-inch stepper motor. With a holding torque of about 19 KG-Cm, NEMA 23 stepper motors are powerful devices [27]. A 2.5A rated current may be found in NEMA 23 stepper motors with a 1.8-degree step angle. Pulse frequency is related to the rotational speed. The driver's output voltage directly correlates to the amount of torque applied [28-31].

Methodology

There are three distinct parts to this system. To achieve the intended motor actuation, the electronics system sends the appropriate control signals to the mechanical system, as illustrated in Figure 5. When the software system issues a command or series of commands, the electronics system responds by

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creating controls for the mechanical system. Figure 5 provides a clear breakdown of the system's technique by separating it into its three constituent parts.

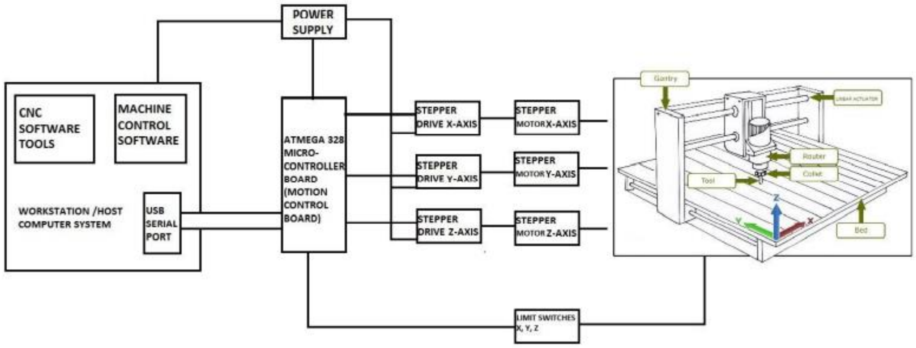

Figure 5. Block diagram of overall process (parts of system design)

Mechanical System

The mechanical system combined with linear rails and linear bearings to allow for 3-axis motion. Each axis is equipped with a stepper motor that receives and responds to a command signal from an electrical circuit. The rotating action of the stepper motor is translated into linear motion by connecting the shaft couplers to the Lead/Ball screw of each axis. Each axis is equipped with a linear rail assembly that can carry loads and move in a straight line independently of the others. Each axis'-controlled motion is accomplished by directly regulating the stepper motor's spin. You may adjust the rate of motion along each axis by sending the appropriate signals to the stepper motor. Each axis of the spindle attached to the end effector may be independently regulated to provide a smooth carving or cutting motion.

Electronics System

Stepper motors, which propel the tool along the specified route, are driven by electronic systems that provide command signals in the desired directions. Included in the electronic system are:

1. Power supply
2. Microcontroller board and
3. Stepper motor driver board 23.

Power Supply

The power supply is the brains of the CNC machine, transforming AC current into DC current and distributing it to the various units. The stepper motor board is powered by 48v, whereas the microcontroller board only gets 12v.

Microcontroller Board

This huge 328p in this case, the motion is managed by an Arduino-based microcontroller development board. It's the central processing unit (CPU) of the CNC system, taking instructions from a computer linked via USB serial interface. In order to create the control signal for the appropriate command signal from the computer system to the stepper motors, which directly controls the motion of the tool path, the Arduino development board is flashed with the GCODE interpreter code, which was developed in the C language. The Stepper Motor Driver Board is what really sends the electrical impulses to the motors from the instructions sent by the computer or software system.

Stepper Motor Driver Board

The NEMA 23 stepper motor is driven by an RMCS-1102 micro-stepping drive, which is selected for its smooth and quiet performance. The microcontroller board sends a control signal to the PULSE and DIR terminals on the driver board, which in turn creates the necessary digital pulse signals for the motor to turn.

G-code Software System

For transmitting G-code files to a built-in hardware interpreter, utilize G-code Sender (Atmega 328). Line by line, G-code Sender will transmit a G-code program from a file to the Atmega 328 microcontroller. The USB connection between the PC and microcontroller will allow the transmission of the G-codes across the serial ports. Grbl Controller is a piece of software for controlling CNC machines, such as 3D milling machines, by means of the G-Code programming language. This doesn't need to be a super-intelligent system; all it has to do is provide a pleasant interface for conveying the user's input to the controller of their choice.

Managing the machine's tool path is done by the G-code firmware. The firmware that understands and compiles G-codes is written in an optimized version of the programming language C. Movement in all three axes is controlled by G-code firmware, which scans each line of the G-code file and then produces the real electrical impulses to the motors. An open-source G-code interpreter/milling controller for the Arduino development board, we've been using grbl. When compared to parallel port-based motion control for CNC milling, Grbl is a more affordable and high-performance option. As long as the Arduino has an Atmega 328, it will function on a standard Arduino (Duemillanove/Uno). All of the AVR chips' ingenious features are put to use in the controller, which is written in highly optimized C, allowing for both exact timing and asynchronous execution. Up to 30kHz of jitter-free control pulses may be maintained using this. It is compatible with G-code that conforms to industry standards and has been tested with the outputs of 29 different CAM programs. Basic functional g-code instructions such as arc, circle, and helix movements are fully supported. While pre-processor support for functions and variables has not yet been implemented, it is possible that this may happen in future updates.

Results and Discussion

The precision of the manufactured CNC Router is evaluated with a battery of tests. Surface flatness, axis perpendicularity, and circularity testing are the three most important examinations. By simply machining a workpiece with a predetermined tool path and federate, these tests may reveal several geometric accuracies, including placement, straightness, roll, pitch, yaw, and perpendicularity. Next, a Coordinate Measuring Machine (CMM) is used to measure the dimensions of the workpiece's newly fabricated features, and the results are evaluated in MATLAB. Surface flatness is checked with a coordinate measuring machine (CMM) while the task is done from a variety of directions. Figure 6 shows the surface of the cutting pathways in various orientations. Path in X-Direction path in Z-Direction path in circular interpolation.

I. Wood **II. MDF** **III. Cardboard**

Figure 6. Engraving surface (test work with different of degree of laser power

Making a perfectly flat surface on the workpiece is how we evaluate its flatness. Checking for unevenness or slant in the bed is what the flatness test is for. Figures 7 and 8 demonstrate two tool trajectories, one along the X-axis and another along the Y-axis, that together produce two distinct surfaces. If a surface is machined in two directions, the surface feature should remain unchanged. Errors in Z-a may be detected, therefore, if there are any noticeable variances between two surfaces.

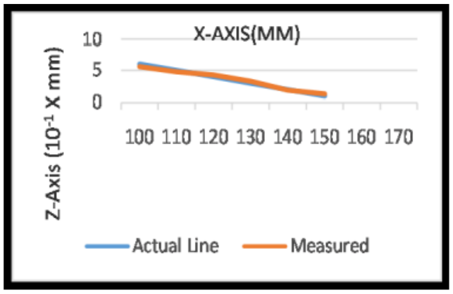

Figure 7. Straightness in x-axis

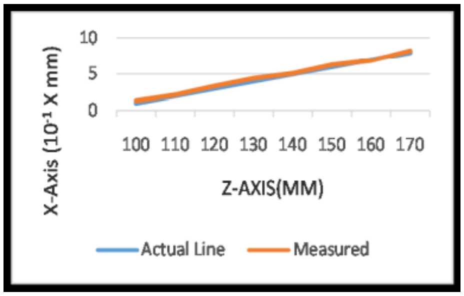

Figure 8. Straightness in z-axis

The test results validation reveals a little misalignment, most likely owing to assembly mistakes. This prototype has a tilt of 0.28 degrees on the X-axis and a tilt of -7.4 degrees on the Y-axis as a result of machine component inaccuracy and alignment problem during assembly. The precision and flatness of the machine would suffer when the feed rate is increased, according to the circular test. As can be seen in Figure 6, one of the processes involved included working with an aluminum blank. Finally, the Fabrication of the Low-cost 3-axis CNC machine provides much more affordability on a low budget with little faults in precision. Gains in fast prototyping flexibility, cost optimization, user friendliness, speed, power use, programming simplicity, and ease of use are all realized.

Conclusions

The test results validation reveals a little misalignment, most likely owing to assembly mistakes. This prototype has a tilt of 0.28 degrees on the X-axis and a tilt of -7.4 degrees on the Y-axis as a result of machine component inaccuracy and alignment problem during assembly. The precision and flatness of the machine would suffer when the feed rate is increased, according to the circular test. As can be seen in Figure 6, one of the processes involved included working with an aluminum blank. Finally, the Fabrication of the Low-cost 3-axis CNC machine provides much more affordability on a low budget with little faults in precision. Gains in fast prototyping flexibility, cost optimization, user friendliness, speed, power use, programming simplicity, and ease of use are all realized.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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