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Practical work for exploring the capabilities and benefits of CNC technology

Abstract

Computer Numerical Control (CNC) technology's precision and complexity in design are two of its greatest strengths. CNC machines can make consistent and accurate cuts, drills, and shapes because they are controlled by computer programs. This precision is especially useful in sectors where producing complex components is mission-critical, such as the aerospace, medical, and automotive industries. The capacity to automate mundane processes is another benefit of CNC technology. CNC machines, once programmed, can mass-produce parts with little to no human intervention, greatly boosting efficiency and lowering production costs. By eliminating the potential for human error, this automation also increases the reliability and consistency of the final output. In addition, CNC machinery can facilitate quicker production runs and shorter setup times, both of which boost productivity. Enhanced productivity has the potential to boost a company's bottom line. Overall, CNC technology has the potential to revolutionize manufacturing by facilitating the rapid, precise, and cost-effective fabrication of intricate parts and components. Since this is a hotspot for innovation, new uses and capabilities appear frequently.

Keywords: CAD, CNC, motor, IRATJ, gcodetool

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Introduction

CNC machine is an advanced manufacturing tool that uses computer software to control the movement and operation of a machine tool. CNC machines can be used to automate a wide range of manufacturing processes, from cutting and drilling to milling and turning. The main components of a CNC machine include a computer, a controller, a motor or motors, and a cutting or shaping tool. The computer is used to create a digital model of the object to be produced, which is then translated into machine code by the controller. The motor or motors are used to move the cutting or shaping tool along the desired path, as specified by the machine code. One of the key advantages of CNC machines is their ability to produce highly precise and complex parts with a high degree of accuracy and consistency. This is due to the fact that CNC machines are capable of executing highly precise and intricate movements with a level of accuracy that is simply not possible with manual machines.[1,2] Another advantage of CNC machines is their versatility. CNC machines can be used to produce a wide range of products, including mechanical parts, electronic components, and even complex medical devices. This makes them highly useful in a wide range of industries, from aerospace and automotive manufacturing to electronics and medical device development. CNC machines come in a variety of sizes and configurations, from small desktop machines suitable for home hobbyists to massive industrial machines capable of producing large-scale industrial components. Some common types of CNC machines include milling machines, lathes, routers, and plasma cutters.[3,4] In addition to their precision and versatility, CNC machines also offer a number of other benefits, including increased production efficiency, reduced labor costs, and improved safety. By automating the manufacturing process, CNC machines can help manufacturers produce high-quality products at a lower cost and with greater speed and efficiency than traditional manufacturing methods.[5] Overall, CNC machines are a critical tool in modern manufacturing, offering a level of precision, efficiency, and versatility that is simply not possible with manual machines. As technology continues to evolve, it is likely that CNC machines will become even more advanced and capable, making them an increasingly important tool in a wide range of industries. This paper outlines the design and construction of a CNC machine for milling shapes using G-code. The paper was undertaken to develop a low-cost CNC machine that can be used in small-scale manufacturing operations. The primary objective of the paper was to create a machine that could be controlled using open-source software and hardware, making it accessible to a wide range of users.[6,7]

Print word

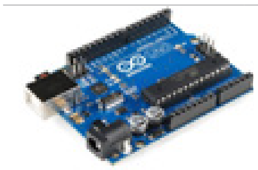
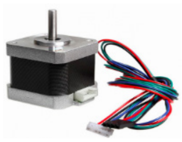
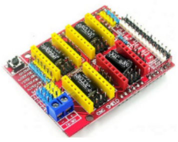
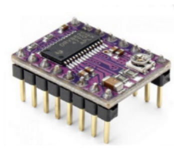
Printing a word using a CNC machine involves using a computer-aided design (CAD) software to create a digital model of the word (**IRATJ**) "international Robotics & Automation Journal" and then using a Gcodetool software to generate the toolpaths required to cut or engrave the word on a material using the CNC machine. Here are the basic steps to print a word using CNC[8,9]:

- **Select the material**: Choose a material that is suitable for the type of CNC machine you are using and the type of word you want to print. For example, if you want to print a word using a laser CNC machine, you would need to select a material that can be engraved with a laser, such as wood, plastic, or metal.
- **Design the Word**: Use a CAD software to design the word you want to print (**IRATJ**), we can use any font or size you prefer, but make sure that the design is suitable for the material you have selected.
- **Generate the Toolpaths**: Use a CAM software to generate the toolpaths required to cut or engrave the word on the material using the CNC machine. The CAM software will convert the digital model of the word into a set of instructions that the CNC machine can understand.
- **Set up the CNC Machine**: Set up the CNC machine with the appropriate tool and material, and load the toolpaths generated by the CAM software onto the machine's controller.
- **Print the Word**: Start the CNC machine and follow the instructions on the controller to print the word on the material. The machine will cut or engrave the word on the material according to the toolpaths generated by the CAM software.

Design and materials

The design of the CNC machine was done using SolidWorks software, which allowed for the creation of detailed 3D models of the machine components. The frame of the machine was made using a combination of 3D-printed parts and wooden pieces, which were selected for their strength and durability.[10] The machine components presented in Table 1.

Table 1 Components of the work

Component	Name	Quantity	Cost	Component	Name	Quantity	Cost
	Arduino Uno	1	5$		Bearings	2	1$
	Stepper motors Nema 17 1.5A	3	6.5$		GT2 belt stabilizer	4	0.89$
	CNC shield v3	1	2.5$		DRV8825	3	2.60$
	Pulleys toothless	3	1.11$		Power supply 12V 10A	1	7$
	pulleys 20 teeth	3	1$		Relay 1 channle 5V	1	1$
	GT2 belt	2m	1$		Fan 12V 0.14A	1	3$

Assembly the components

The CNC machine was designed to move in three axes "X, Y, and Z" allowing it to create shapes in three dimensions. The CNC shield v3 and motor drives were connected to the stepper motors and the Arduino Uno controller, allowing for precise control of the machine's movement. The CNC shield v3 provided a simple interface for connecting the stepper motors and motor drives, while the motor drives were responsible for amplifying the current supplied to the stepper motors to achieve the required torque. The wooden part was designed to provide a stable base for the machine and to ensure accurate movement of the machine in all three axes. The frame was assembled using 3D-printed parts and wooden pieces as shown in Figure1, which were selected for their strength and durability.[11–13]

X – Axis

With SolidWorks we designed the shape in Figure 2a, so we can place the wood part on it to connect between both of supports, and made hole on front plan so we can pass the belt through its Fig.2b and from side plane we made another hole so we can pass the screw through its Figure 2c.

This piece Figure 3a is designed to increase safety in the movement of the electric drill in the Y axis, as it is likely that the machine will overturn from this side in the event that the electric drill is near, as most of the weight becomes on the same side (the weight of the electric drill with the three motors), unlike if the electric drill is farther away a point, and from side plane we made a hole so we can pass the screw through it Figure 3b.

Second part we designed is Figure 4a and also can place the second wood part on it to connect between both of supports, and from side plane made a hole so we can pass the screw through it Figure 4b.

Then in Figure 5 Insert the wood parts and connect all x – axis part with 50cm screw.

Y – Axis

We designed the shape "Plate" in Figure 6a, the plate is designed to moves the electric drill in (x, y axis) by hold two stepper motors (x and y axis), two (Pulleys toothless), and wood part. For x - axis motor we installed two of "Pulleys toothless" to providing grip for the x-axis GT2 belt and the toothed pulley which goes on the stepper motor as shown in Figure 6b.

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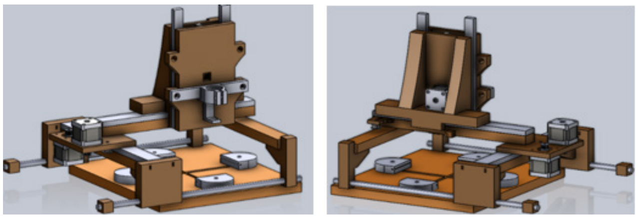

Figure 1 3D-printed parts of the practical work.

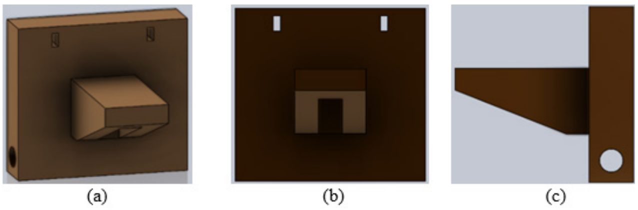

Figure 2 The shape of the support first part (3D, Frontal view and lateral view respectively).

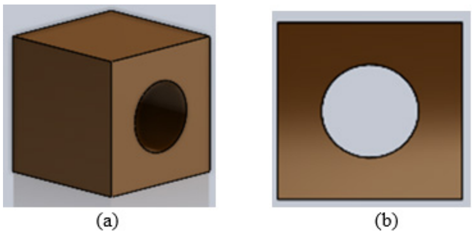

Figure 3 Part for increasing safety during the movement of the electric drill in the Y axis (3D and lateral view).

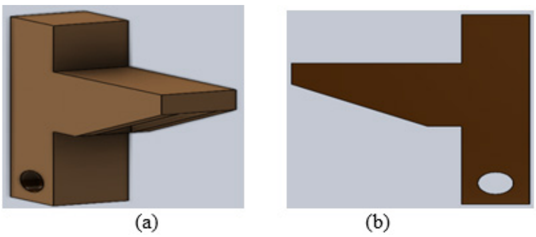

Figure 4 The Shape of the support second part (3D lateral view respectively).

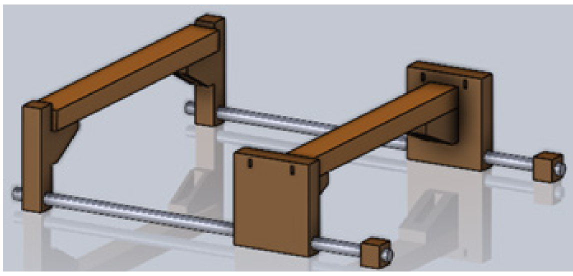

Figure 5 Connect all x – axis parts.

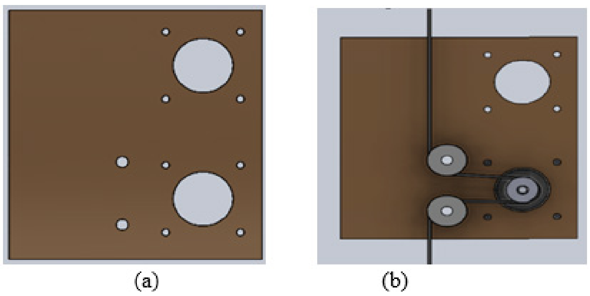

Figure 6 A The part for moving the electric drill in the x and y axes.

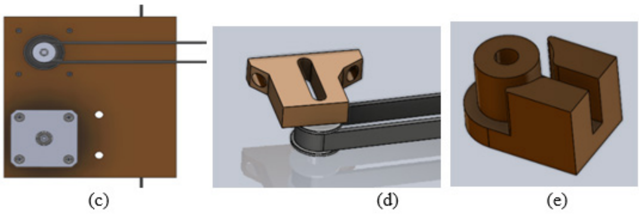

Figure 6 Components for movement in the y-axis direction.

For y – axis motor we installed it in another face of the plate Figure 6c, and we only need one idler pulley which goes on the other side of the rail as shown in Figure 7d, as the belt for this axis will be installed in a loop to attaching the sliding block, I made these cool belt connectors, where the belt goes around a hollow shaft and in between two walls that doesn't allow the belt to move as presented in Figure 6e (2 - e).

The sliding block in Figure 7 its designed to moves the electric drill in (Y, Z axis) by hold the (Z – axis) stepper motor, electric drill plate in Fig. 8 and, electric drill holder in Figure 9.

After install all part of "Y – Axis" with 40cm wood part Figure 10.

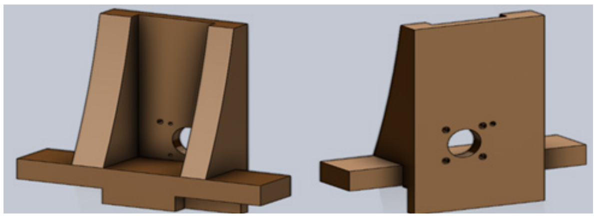

Figure 7 The sliding block for the movement of the drill in the y and z directions.

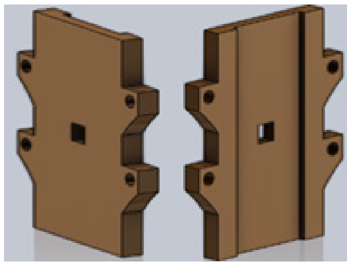

Figure 8 Stepper motor holder.

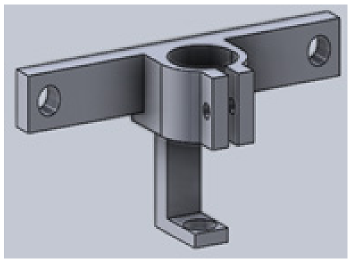

Figure 9 Electric drill holder.

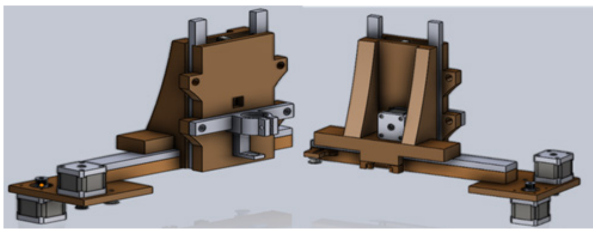

Figure 10 Connect all y – axis parts.

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Z – Axis

Initially, the Z-axis had some issues with stability and accuracy (Figure 11), causing errors in the milling process. After some investigation, it was discovered that the "Ball Bearing Slide" parts supporting the Z-axis were not providing enough rigidity, causing the Z-axis to move erratically during operation. Additionally, the Z-axis motor was experiencing strong torque, leading to inaccuracies in the milling depth. To solve these problems, the Z-axis was redesigned with additional 3D-printed parts and a reduction in the motor torque. The new design included a more robust mount for the Z-axis stepper motor, a stronger support. After implementing the redesign, the stability and accuracy of the Z-axis were greatly improved, resulting in a higher quality milling process with more consistent shapes. The reduction in motor torque also helped to prevent overloading of the Z-axis, leading to smoother and more precise movement of the milling bit (Figure 12).

Overall, the combination of the three stepper motors, pulleys, belts, CNC shield v3, motor drives, and Arduino Uno controller allowed for precise movement of the machine in all three axes, enabling it to mill shapes in three dimensions. Also, we designed supports to hold the PCB plate and installed them on wood plate as shown in Figure 13.

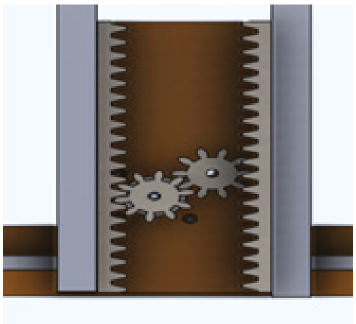

Figure 11 The bearing supporting the movement of the motor in the Z direction.

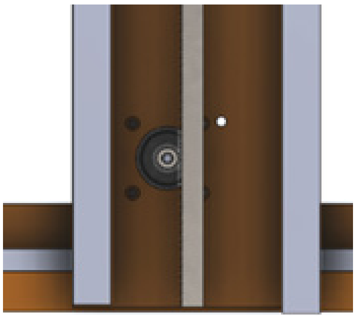

Figure 12 Insurance precise movement of the milling bit.

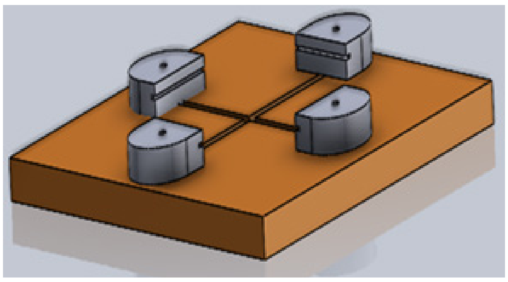

Figure 13 Supports and hold the PCB plate.

The Box

We designed the box in Figure 14 to hold the "Arduino UNO, CNC shield and Relay" with holes for "ports, cables, and ventilation" and installed the fan on top of the box.

Figure 15 represents the 3D shape of the circle after it has been assembled and is now ready to work and print various shapes and words.

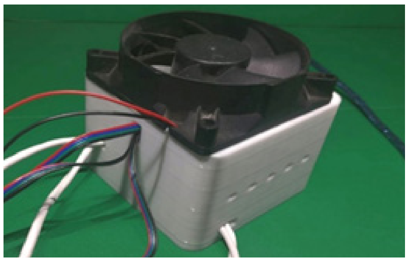

Figure 14 The practical circuit component assembly box.

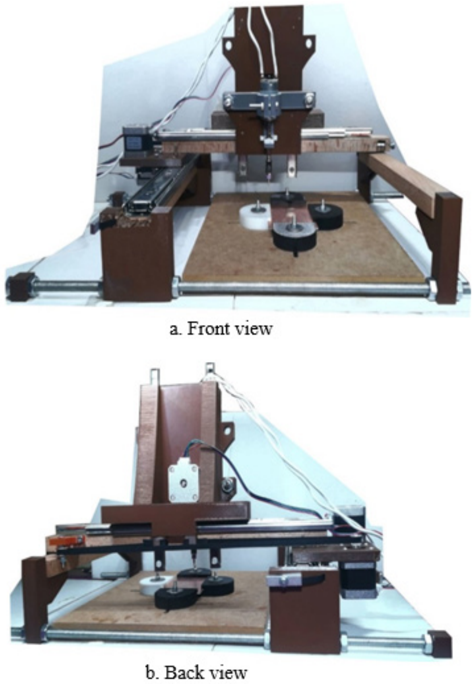

Figure 15 3D of experimental circuit designed.

CNC Machine Operation

The CNC machine was tested by milling several shapes using G-code. The G-code was created using open-source software and was uploaded to the Arduino Uno controller using a USB cable. The milling process was successful, producing accurate shapes with smooth edges. The milling process was tested using various shapes created using open-source software such as Figure 16. The shapes were saved in G-code format and uploaded to the Arduino Uno controller using the Universal G-code sender (UGS) app.[14–16]

The machine was operated using the GRBL firmware, which is an open-source firmware designed for controlling CNC machines. The firmware was uploaded to the Arduino Uno controller, which allowed the machine to be controlled using G-code commands. The Universal G-code Sender (UGS) app was used to send G-code commands to the CNC machine and control its movement (Figure 17). To ensure accurate movement of the machine, calibration of the stepper motors was performed using the UGS app. The app allowed for precise calibration of the steps per millimeter (SPM) of each stepper motor, which affected the accuracy of the milling process. The calibration

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process involved adjusting the SPM values until the machine moved the desired distance with minimal error.[17,18]

Figure 18 shows how the abbreviated name of the International Robotics & Automation Journal, represented by the abbreviation **IRATJ**, was printed. It was printed with very high accuracy and at a low cost, using the practical circuit whose components were assembled.[19,20]

Figure 16 Abbreviation for International Robotics and Automation Journal.

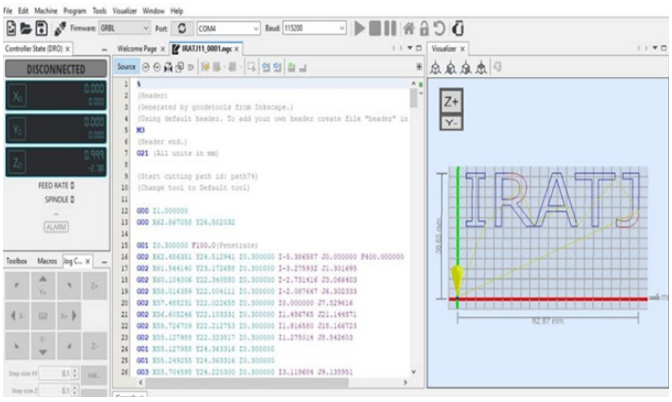

Figure 17 Gcood tools and applications.

Figure 18 Print IRATJ using experimental circuit.

Conclusion

To summarize, the CNC machine has proven to be a successful and cost-effective tool for small-scale manufacturing operations. The use of open-source software and hardware has made it accessible to a wider range of users. Based on the lessons learned during the study, accurate alignment of machine components and precise calibration of stepper motors are critical. Future enhancements may include the integration of higher torque stepper motors and feedback systems to increase machine accuracy. The research delves into various aspects of computer numerical control technology and its modern manufacturing applications. CNC technology has revolutionized the manufacturing industry by enabling efficient, precise, and automated production of complex components. This study examines the capabilities of CNC technology, including its ability to produce intricate designs, automate repetitive tasks, and improve production efficiency. We also explore the advantages of CNC technology, such as reduced labor costs, increased production speed, and improved product quality. Furthermore, we discuss the challenges and limitations of CNC technology and its potential impact on the manufacturing industry's future. The goal of this paper is to provide a comprehensive overview of CNC technology and its potential to transform the manufacturing industry.

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None.

Conflicts of interests

Author declares that there is no conflict of interest.

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