Romanian Journal of Petroleum & Gas Technology
VOL. V (LXXVI) • No. 2/2024

THE DESIGN AND IMPLEMENTATION OF AN AUTOMATED CNC TYPEWRITER

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DOI: 10.51865/JPGT.2024.02.05

ABSTRACT

The paper presents the essential theoretical elements related to the construction and operation of numerical control machines, starting from a study of the theoretical aspects related to the design of a CNC typewriter. The block diagrams of the machine, the interconnections between the component blocks and the operation of the whole system are highlighted. The paper also describes the implementation of the typewriter. It starts from a detailed diagram of the wiring and connections between the component elements, up to the presentation and commentary of how to create the program for the microcontroller used. Finally, the testing and operation of this CNC is detailed, from the design of the drawing to its actual realization, with the help of the designed and implemented assembly. CNC systems allow the repetitive production of the same parts, exactly the same and without deviations. Unlike a human operator who cannot execute two identical parts, the repeatability achieved by machines with numerical controls is clearly superior, so the reproducibility component is ensured.

Keywords: CNC, G-code, servomotor, MPP, Arduino

INTRODUCTION

Designing and making an automatic CNC typewriter is a complex and exciting endeavor in the field of automation and applied informatics. Automatic CNC typewriters represent an impressive jointing of technology and creativity, offering the potential to revolutionize the way we interact with writing, drawing and other creative activities [1-23].

The evolution of numerical control (CNC) systems has been a continuous process of development and improvement of machine tool control technology in the manufacturing industry. The first CNC systems appeared in the 1950s and evolved from mechanical systems to modern computer-based systems with advanced features of control, precision and efficiency. Then, CNC systems evolved towards hydraulic and electro-hydraulic systems, which offered an increased degree of precision, allowing the creation of quality products in large or small series, with lower costs and with a reduced degree of error. In the 1980s, CNC systems evolved to computer-based systems that allowed greater flexibility and versatility in the manufacturing process. They allowing the rapid change of finished products, as well as the performance of complex operations, such as cutting complicated shapes or milling curved surfaces [1-23].

In recent years, CNC machines have seen a significant increase in the number of applications in which they are used, like PCB drawing and drilling processes [10], cutting processes [22]. All these applications have led to the development of the components necessary to drive stepper motors, programmable modules and drawing systems. Numerical control systems have the main advantage of providing high precision and repeatability in the execution of work operations [1]. Regarding CNC typewriter can be found in the specialized literature some CNC plotter [13] and dual axis writing machine [19].

Starting from a study of the theoretical aspects related to the design of a CNC typewriter, the scope of this paper is design and building of an accurate, flexible and cost-effective machine. This modern CNC system is based on advanced technologies, starting to 3D printing for almost all components, then using fast processors and graphical interface operating systems.

CNC TYPEWRITER DESIGN

CNC systems are used in a wide range of applications in different industries. Considering the precision, efficiency and flexibility of these machines in the processing process, they have been widely adopted in many of the industries: metal processing, automobile industry, aerospace industry, medical component manufacturing, electronic industry, furniture and wood industry, jewelry industry. The block diagram of the typewriter is shown in Figure 1.

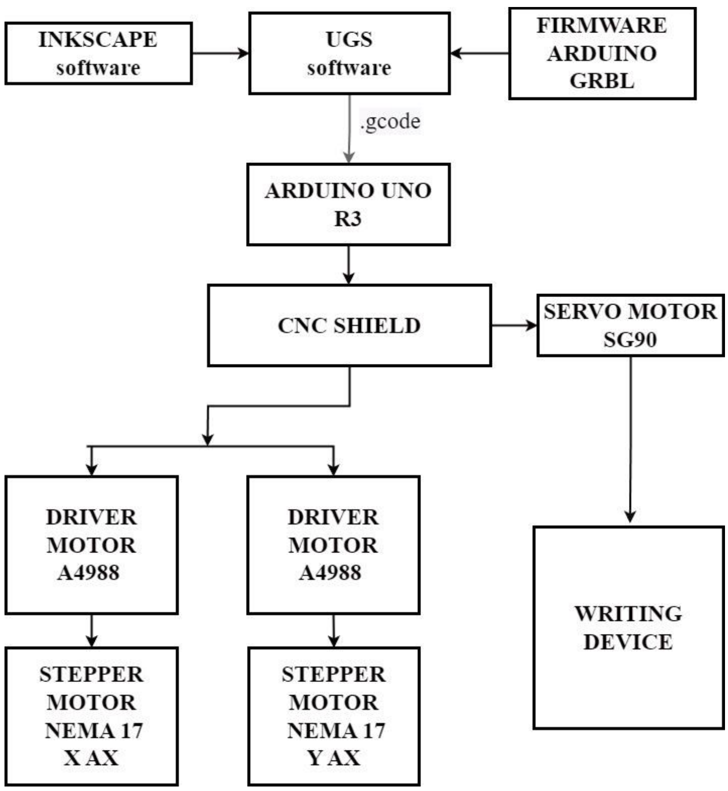

***Figure 1**. Block diagram of the CNC Typewriter*

The designed assembly is mobile and can be placed on any flat surface. The writing instrument is moved in the *XY* plane. Changing the position of the tool on the *Z* axis is done with the help of a servo motor connected to the CNC shield. Coordinate movement is done with the help of stepper motors. Control of stepper motors is done by drivers (one for each motor). They are connected to an electronic board connected to an Arduino Uno minicomputer through which the connection to the computer is made. Power for the process computer comes from a 12 V power supply.

SG90 servomotor (Figure 2) is an essential component for precisely controlling the movements of the *Z*-axis in a CNC typewriter. This compact and lightweight servo is ideal for applications that require precise and fast movements. Characterized by its small size and weight of only 9g, the SG90 is strong enough to handle writing instruments on the vertical axis with ease.

The SG90 motor is controlled by PWM (Pulse Width Modulation) signals, allowing precise position settings. Users can program and calibrate the servo to meet the exact needs of their project. In conclusion, the SG90 servomotor is an excellent choice for its application in CNC typewriters due to its combination of performance, reliability and ease of use.

Figure 2. *Servomotor SG90* [30]

Nema 17 stepper motors (MPP) were used for the advance mechanisms on the *X*, *Y* axes. These motors allow stepwise adjustment of the advance speeds according to the values of the control pulses transmitted by the controller through the driver. The stepper motors are connected to the shield module for Arduino, which can control, with the GRBL software, a CNC. The A4988 driver was used to control the stepper motors (Figure 3).

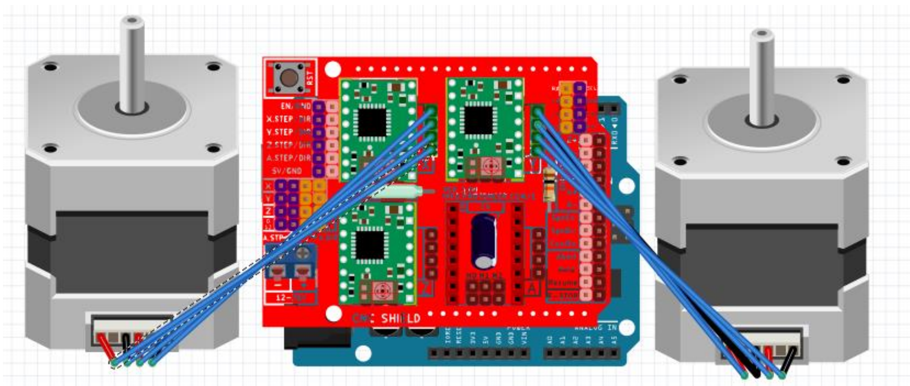

Figure 3. *Motor assembly – driver*

Arduino Uno is an open-source development board based on an ATmega328P microcontroller. With a simple and easy-to-use architecture, the Arduino Uno provides an accessible platform for creating and programming interactive devices. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller (Figure 4).

***Figure 4**. Arduino Uno* [31]

To extend the functionality of the Arduino Uno, various shields (extension boards) are available. They connect directly to the board and add additional capabilities such as wireless communications, specialized sensors or motor control. Shields are designed to provide simple and quick integration, eliminating the need for complicated connections. A principle diagram of the designed CNC, made in the Blender application, is presented in Figure 5.

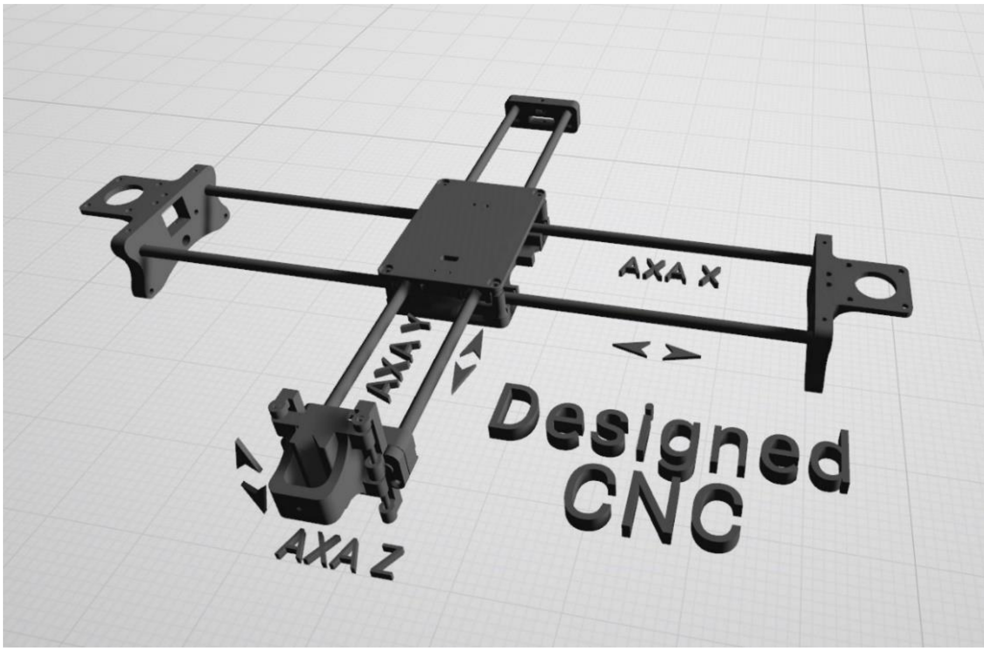

***Figure 5.** Designed CNC*

CNC TYPEWRITER HARDWARE IMPLEMENTATION

The first stage in the realization of this CNC machine was the design, in the Blender program, of all the components. After drawing them, they were physically made by 3D printing (Figure 6). The Cura slicer program was used, instead of the most frequently used one, Sli3er, but with a much lower success rate. The necessary settings were made to print the parts, using an infill of 75%. The print layer height was set between 0.10mm and 0.20mm and Hatchbox Black PLA filament was used for all parts. For components such as the writing tool holder, slider, *X*-axis left and *X*-axis right, supports were added to ensure correct printing, and after printing, they were removed. In terms of print time, the longest piece took about 9 hours to print, while the shortest piece only took 30 minutes.

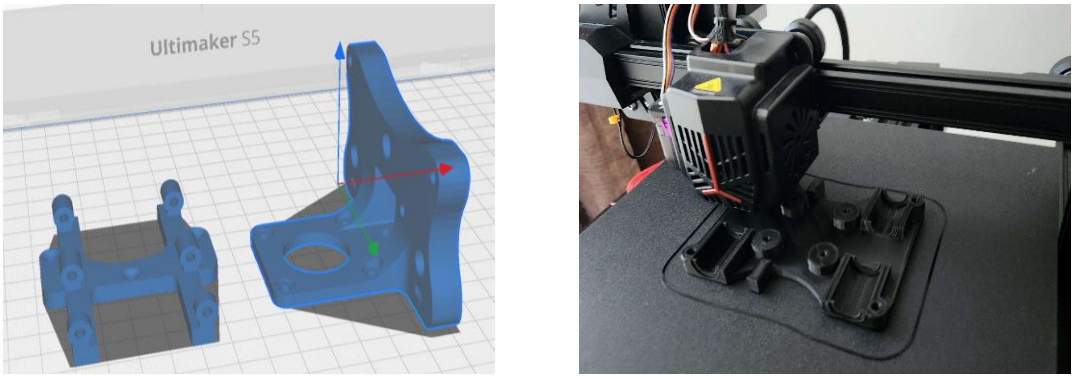

Figure 6. *3D printing for the X-axis component*

The guidance system in the *XY* plane was made with the help of two metal guiding axes (bars) for each movement direction. Each bar is inserted into the printed assembly where 4 bearings are mounted with the help of which the moving parts slide. Using bearings has the advantage of achieving precise guidance.

The movement in the *XY* plane of the platform in Figure 7 is realized with the help of a Cartesian motion system based on belts, which uses stepper motors and rollers. The system has two stepper motors, mounted at the ends of the rods, which are responsible for driving the movement on the *X* and *Y* axes. The GT2 belts are attached to the motors and pass through a set of rollers and guides, thereby converting the rotational movement of the motors in a linear movement of the platform.

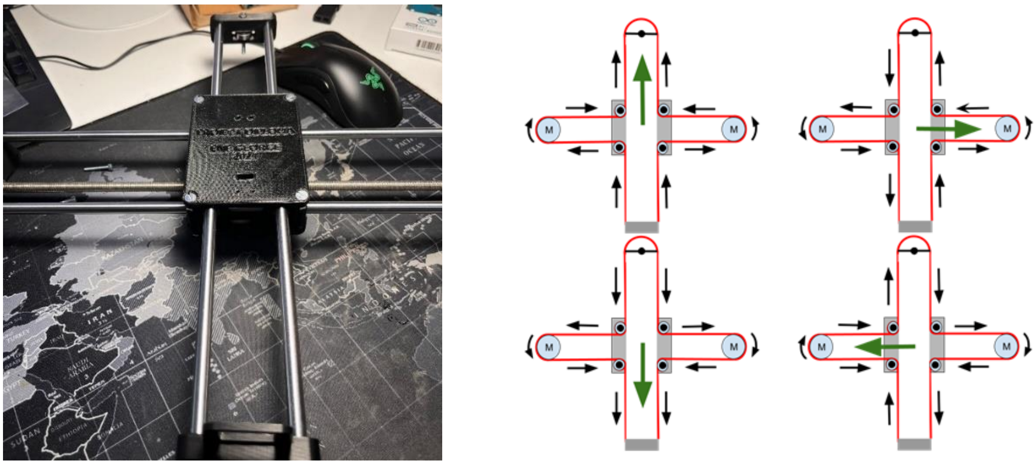

Figure 7. *The XY assembly and the mode of operation of the transmission belts*

Making the assembly for moving on the *Z* axis (the writing instrument), connecting the CNC shield from the Arduino and the MPP drivers is presented in Figure 8. The final assembly can be found in Figure 9. The connection diagram for the entire assembly is presented in Figure 10.

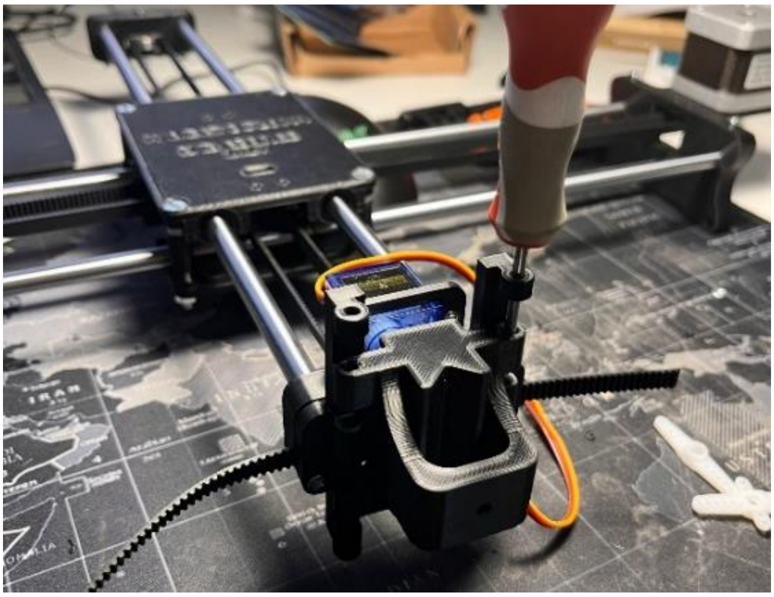

Figure 8. *Assembly for moving on the Z axis*

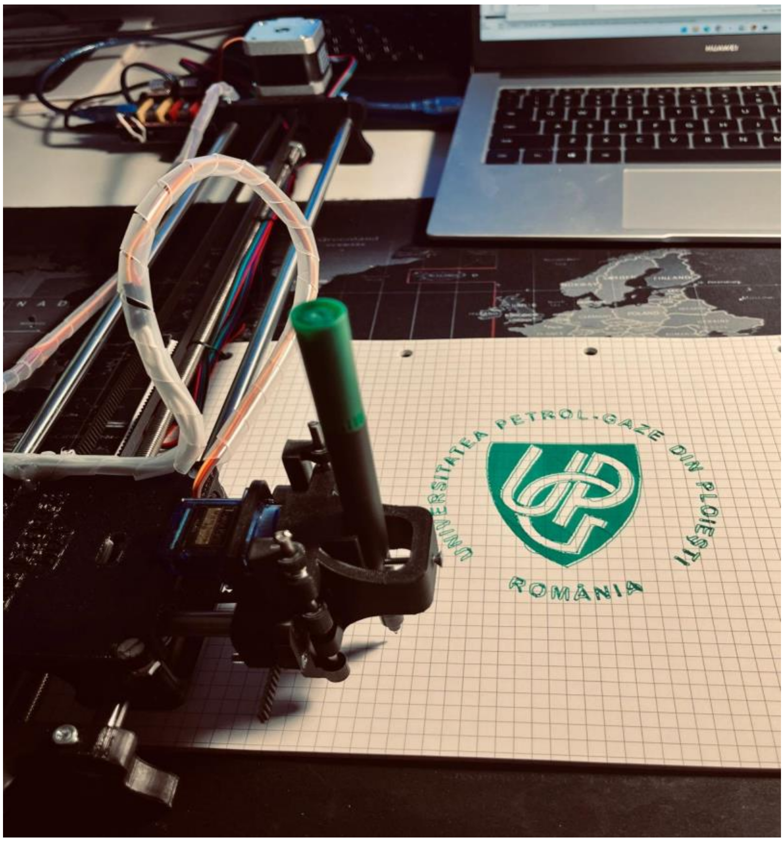

Figure 10. *CNC Typewriter assembly*

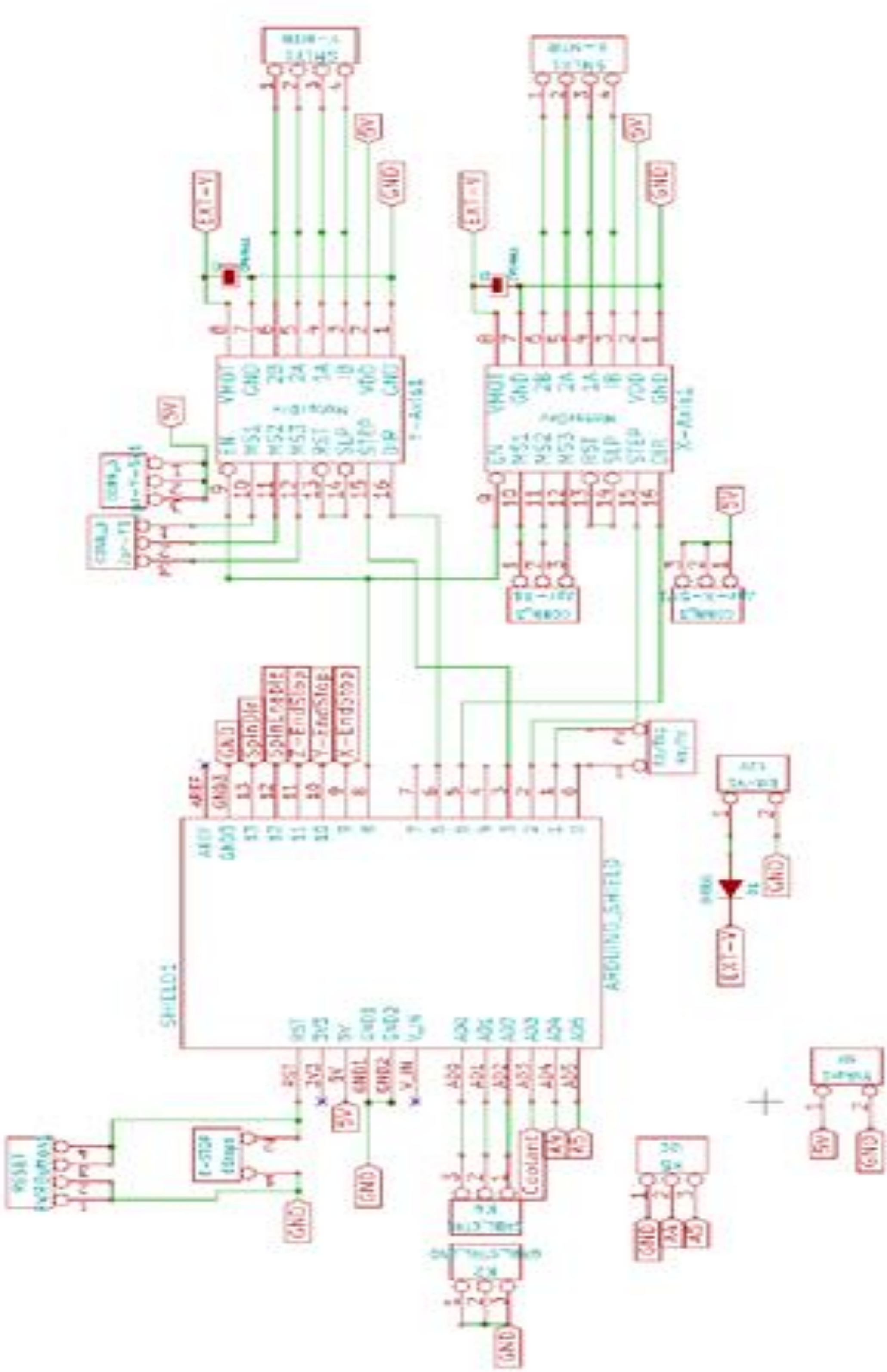

Figure 10. *Electrical connection diagram of the CNC*

CNC TYPEWRITER TESTING

Using the Universal G-code MI GRBL application, the movements on the *X* and *Y* axes are first tested. For the *Z* axis, macro commands must be created to raise and lower the writing instrument (Figure 11).

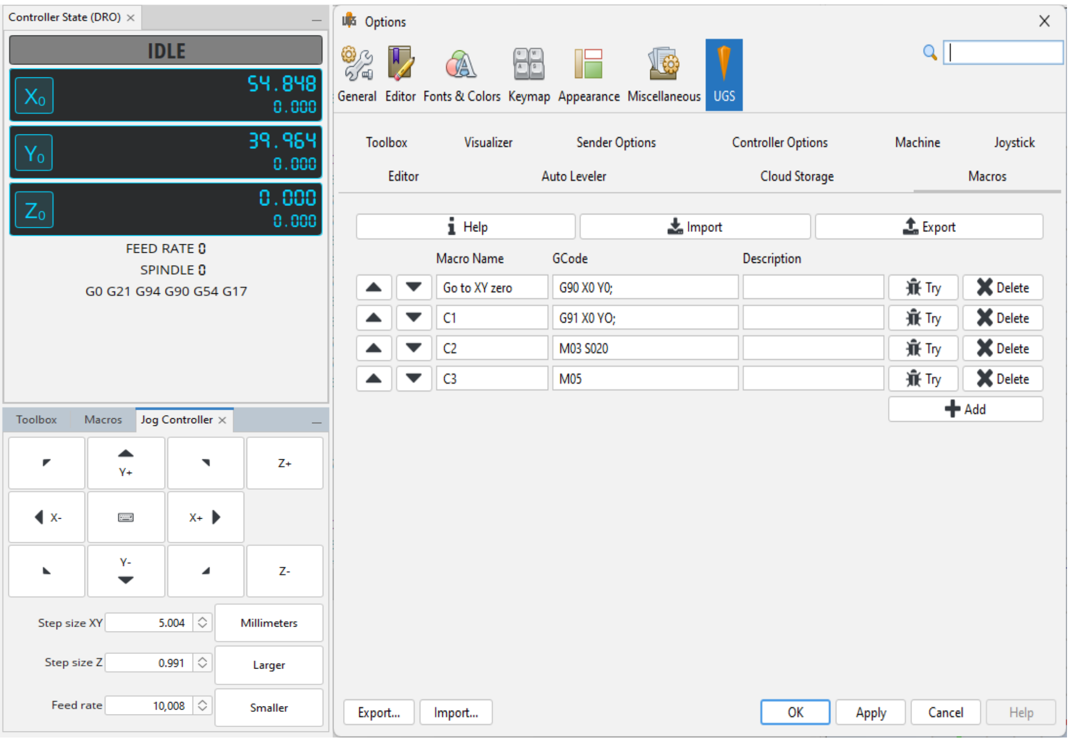

Figure 11. *Testing movements on the X, Y axes*

After completing these steps, the equipment is ready for functionality testing. For this, a drawing is imported from the Inskape application, which will be converted into G-code (Figure 12).

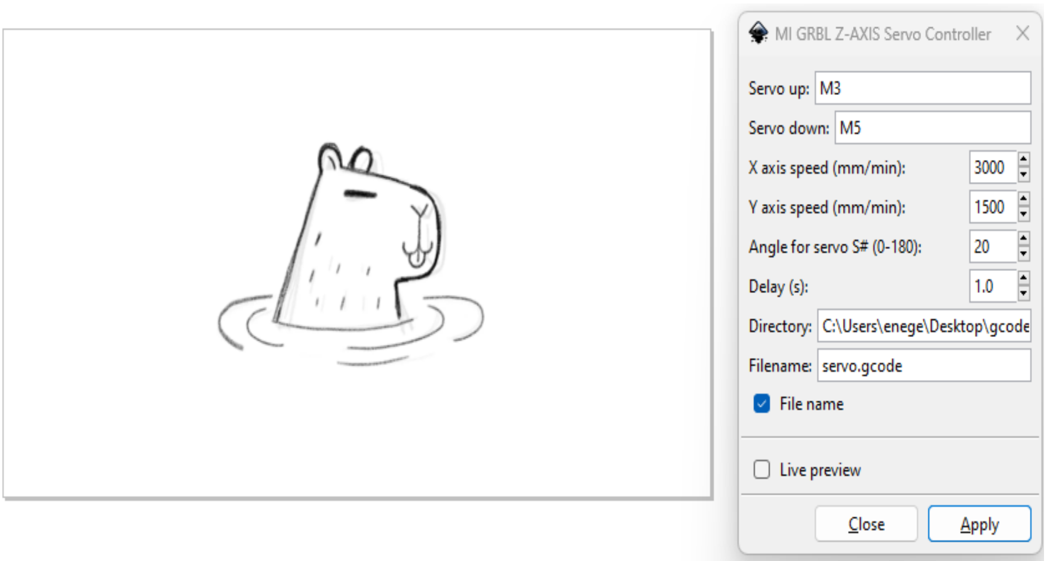

Figure 12. *Execution drawing made in the Inskape application*

G-code is the most widely used CNC programming language, available in a wide variety of implementations. G code instructions can indicate paths of movement, either straight lines or curves. Movement speed, also known as feed rate, activates tool-specific options and changes machine configurations. To generate the G-code instructions, a free program "Universal G-code sender" was used, which transforms part sketches into a set of instructions that can be followed by the CNC machine. The G-code generated for this image contains over 900 commands. Figure 13 shows some lines of code.

```
M03 S20
G90
G21
G1F10000
G1 X38.1655 Y8.0369
G4P0.10000000149011612
M05 S0
G4P0.10000000149011612
G1F3000.000000
G1 X38.2018 Y8.181F3000.000000
G2 X40.7527 Y8.3122 I2.4758 J-23.2691
G2 X42.9031 Y8.2193 I-0.0763 J-26.6888
G1 X42,962 Y8.128
G1 X42.8022 Y8.007
G2 X40.8267 Y7.9358 I-2.1679 J32.6986
G2 X38.8467 Y7,983 I-0.1957 J33.3351
G1 X38,648 Y8.1027
G1 X38.5871 Y8.1308
```

Figure 13. *G-code sequence*

The result obtained with a CNC typewriter is in Figure 14. During testing, various parameters were adjusted to optimize drawing quality. The speed on each axis and the angle for the servomotors were adjusted, these adjustments allow obtaining precise and high quality images. At the same time, to maintain a constant movement and avoid interruptions or errors during the process, the mechanical tension of the belt was adjusted to prevent slippage. These adjustments allow obtaining precise lines and minimal distortions.

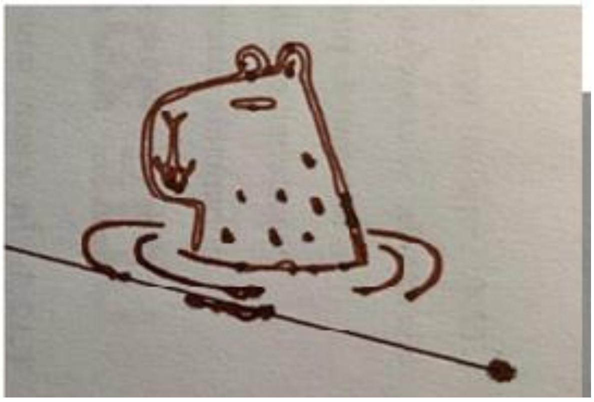

***Figure 14**. Drawing with a CNC typewriter*

CONCLUSIONS

A large number of tests were performed, using drawings executed in AutoCAD as well as text passages, and the results were satisfactory. However, 10% of the tests showed errors due to uncontrollable vibrations, belt slippage, or generation of wrong G-code programs, which led to incorrect axis configuration and mirrored patterns.

Errors in the operation of automatic machines may arise from the design of the typewriter, especially due to the planar irregularity of the mechanical components used in construction and the dimensional difference between purchased components. However, by reducing the working speed of the stepper motors and selecting high-resolution models, these errors can be greatly reduced. However, this approach can lead to a large increase in the time required for write operations and thus the cost. Therefore, the optimization of all these aspects is sought to obtain a high quality of the final product at the lowest possible cost.

CNC systems offer several advantages over other manufacturing methods. They allow the manufacture of parts with precise dimensions and complex shapes. The precision of a CNC machine is very high and reaches 5-10 micrometers for professional machines, a precision that cannot be achieved by a human operator. CNC systems allow the repetitive production of the same parts, exactly the same and without deviations. Unlike a human operator who cannot execute two identical parts, the repeatability achieved by machines with numerical controls is clearly superior, so the reproducibility component is ensured.

Current and future trends in the development of CNC systems include the integration of artificial intelligence and collaborative robotics. CNC systems are becoming increasingly integrated with other manufacturing technologies and processes. For example, integration with industrial robots, measuring systems and advanced sensors enables increased functionality and flexibility. Automation increases efficiency and reduces production time. Technological developments in electronics and computer science enable the use of more sophisticated algorithms for controlling the movement and operation of machine tools. CNC systems are becoming more accurate, faster and easier to use. The integration of artificial intelligence and machine learning into CNC systems opens up new possibilities. Machine tools can learn and adapt to different situations, anticipate errors and optimize production processes. CNC systems are increasingly integrated into intelligent manufacturing networks, according to the concept of Industry 4.0. This involves connectivity with other machines and equipment, real-time data exchange and the use of data analysis to optimize production [16]. The development of intuitive and friendly user interfaces facilitates the programming and use of CNC systems. This reduces training time and allows operators to work efficiently with the equipment.

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Received: June 2024; Revised: July 2024; Accepted: July 2024; Published: July 2024