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Control of a CNC laser engraver machine for non-metallic materials

Control de una maquina CNC grabador láser para materiales no metálicos

PACHECO-ALVARADO, Luis Kevin†*, GONZALEZ-MONZON, Ana Lilia, PIÑA-ALCANTARA Henry Christopher and TORRES-ARREOLA, León Guillermo

Tecnológico de Estudios Superiores de Jilotepec, México

ID 1st Author: *Luis Kevin, Pacheco-Alvarado* / **ORC ID:** 0000-0002-0722-1346, **CVU CONACYT ID**: 883154

ID 1st Co-author: *Ana Lilia, González-Monzón* / **ORC ID:** 0000-0002-0280-0525, **CVU CONACYT ID**: 151293

ID 2nd Co-author: *Henry Christopher, Piña-Alcantara* / **ORC ID:** 0000-0001-5726-2915, **CVU CONACYT ID**: 719620

ID 3rd Co-author: *León Guillermo, Torres-Arreola* / **ORC ID:** 0000-0002-7694-9613, **CVU CONACYT ID**: 1205387

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Abstract

The present work consists of the development of a control system by means of a microprocessor for a prototype of engraving of non-metallic materials using a semiconductor laser, which has the purpose of carrying out said process without the use of any image processing software as they do. other common marketing devices. This prototype is based on a Cartesian positioning robot, built with a 20mm structural aluminum profile, a 450nm wavelength laser module at 1W of power adjustable by PWM pulse width modulation, 3 motors with Nema 17 bipolar steps, an ATMega2560 microcontroller and a CNC shield card. As a result, we obtain a prototype of a laser engraver with a microcontroller control system, which according to the tests carried out has an efficiency of 95%, capable of carrying out a maximum of 27 engraving processes every 60 minutes with a 30-minute break and that does not use image processing software.

Microcontroller, CNC, Control

Resumen

El presente trabajo consiste en el desarrollo de un sistema de control mediante un microprocesador para un prototipo de grabado de materiales no metálicos utilizando un láser de semiconductor, que tiene el propósito realizar dicho proceso sin el uso de algún software de procesamiento de imágenes como lo hacen otros dispositivos de comercialización común. Este prototipo está basado en un robot de posicionamiento cartesiano, construido con perfil de aluminio estructural de 20mm, un módulo láser de 450nm de longitud de onda a 1 W de potencia regulable mediante modulación de ancho de pulso PWM por sus siglas en inglés, 3 motores a pasos bipolares Nema 17, un microcontrolador ATMega2560 y una tarjeta CNC shield. Como resultado obtenemos un prototipo de grabador láser con un sistema de control mediante microcontrolador, que según las pruebas realizadas tiene una eficiencia del 95%, capaz de realizar un máximo de 27 procesos de grabado cada 60 minutos con 30 minutos de descanso y que no utiliza un software de procesamiento de imágenes.

Microcontrolador, CNC, Control

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*Correspondence to Author (e-mail: ing.kpacheco@hotmail.com)
†Researcher contributing as first Author.

Introduction

Currently, there are a number of machines on the market that perform engraving and cutting processes of metallic and non-metallic materials by means of working tools that can vary according to the type of device and according to the needs and demands of the customers. There are systems that work using roughing as a process of transformation of materials and there are other processes such as steaming that offer the possibility of having greater precision in the engraving or cutting.

In a constant process of innovation for the improvement of techniques for the manufacture of raw materials, we have worked hard to increase productivity and greater precision in the work performed. The best known techniques are: turning, drilling, planing, grinding, milling and scribing, just to mention a few.

The worldwide dynamics of globalization in production presents us with the great need to automate these material manufacturing techniques in order to reduce time and eliminate some errors that can become common due to human intervention, as well as to achieve greater productivity and precision. This can be possible thanks to Computer Numerical Control (CNC) machines, which is complemented with an abrasive tool.

This work addresses the implementation of a microcontroller control system for an engraving prototype whose tool is a 450 nm wavelength coherent light emitting diode for non-metallic materials.

Development

For the development of the project, the methodology shown in Figure 1 was used, where it mentions the steps to design and assemble the laser engraver prototype, as well as to develop the control system using a microcontroller.

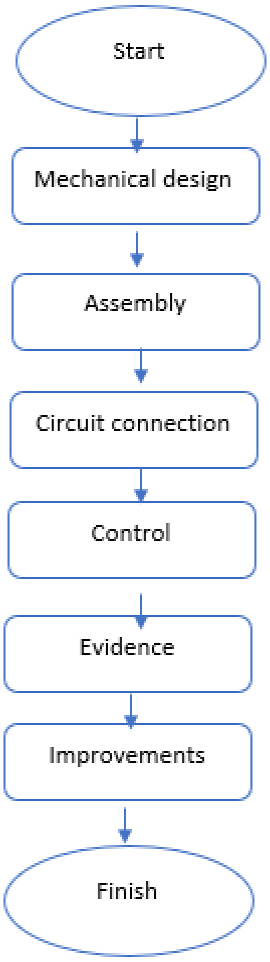


Figure 1 Methodology flowchart
Source (project contribution, unpublished)

Mechanical Design

The laser recording system is a positioner in Cartesian configuration, it has a structure with a 20mm IPS profile, which is formed by a transmission through a toothed belt and plastic wheels with bearings, through stepper motors, it is integrated by several pieces machined in MDF material of 6mm thickness.

Two 20x20 mm by 250 mm long IPS structural profiles are used, which constitute the width of the frame of the main structure of the prototype, two 20x20 mm by 350 mm long IPS aluminum structural profiles are used, which constitute the length of the frame of the main structure of the prototype, also 4 aluminum corner pieces are used as angle supports and as fastening of the aluminum structural profiles described above, together with the 4 square nuts of 3/8" and M5 screws. The representation of the frame of the main structure of the prototype can be seen in Figure 2.

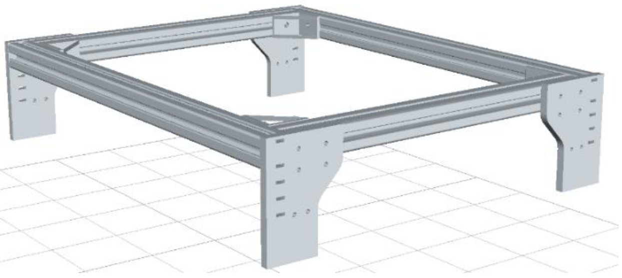


Figure 2 Representation of the base structure of the laser engraver system in CAD software
Source (project contribution, unpublished)

The Y axis of the laser engraver prototype slides directly on the frame of the main structure of the prototype and, unlike the X axis, this one contemplates the use of 2 stepper motors that with their coordinated movements create a uniform displacement.

Figure 3 shows a representation of the Y axis mounted on the frame of the main structure of the laser engraver prototype, drawn in CAD software, the pieces shown in yellow, integrate all the elements that constitute the Y axis.

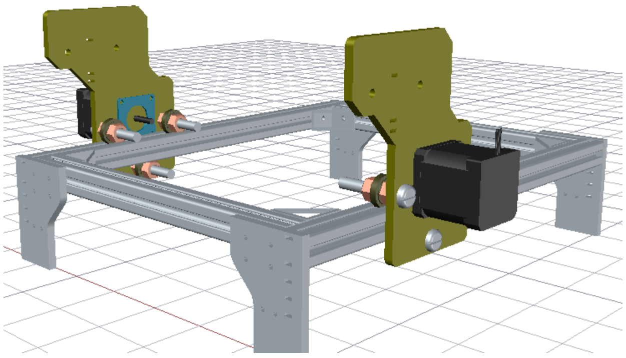


Figure 3 Representation of the Y-axis on the frame of the main structure of the prototype in CAD software
Source (project contribution, unpublished)

In the same way, Figure 4 shows a representation of the mounting of the X axis on the Y axis of the laser engraver prototype of the present work, drawn in CAD software.

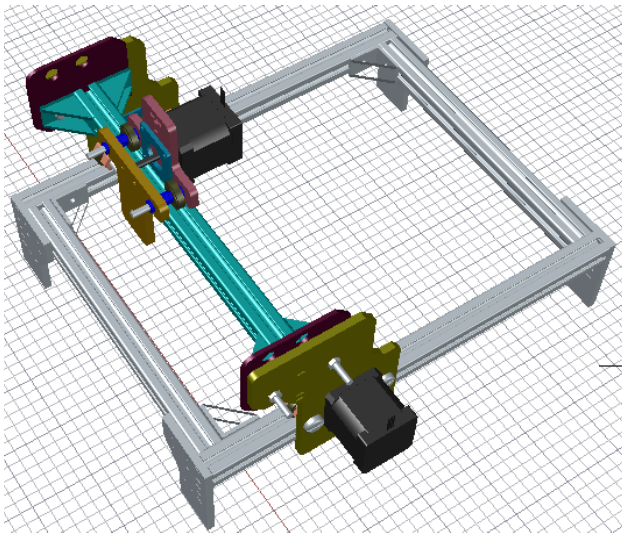


Figure 4 Representation of the X-axis mounted on the Y-axis of the laser engraver prototype in CAD software.
Source (project contribution, unpublished)

Mechanical Assembly

To carry out the mechanical assembly, we used the elements shown in Figure 5, which are half-inch long M5 screws, 2 IPS aluminum structural profiles 20x20 mm by 350 mm long, 2 IPS aluminum structural profiles 20x20 mm by 250 mm long, 4 angled aluminum corner pieces and 3/8-inch square nuts for M5 screws and Nema 17 stepper motors.

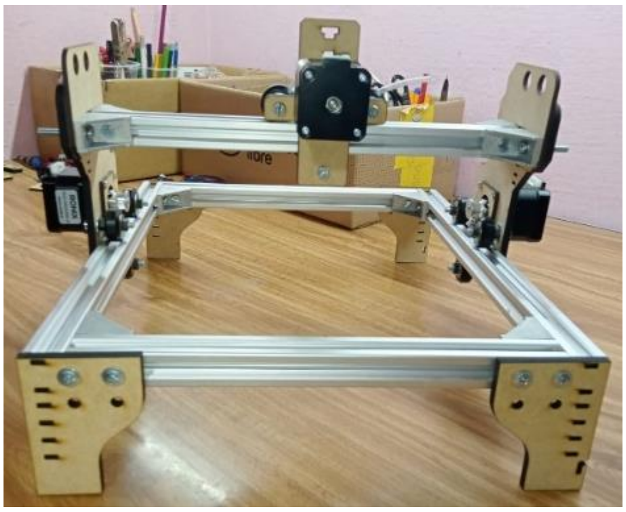


Figure 5 Prototype laser engraver with 2 axes and main structure
Source (project contribution, unpublished)

Circuit connection of the laser engraver prototype

The connection of the circuits of the laser engraver prototype can be seen in Figure 6, which has two 12V power supplies, one source will serve for the control system integrated by the microcontroller, the other source supplies power to the drivers and stepper motors.

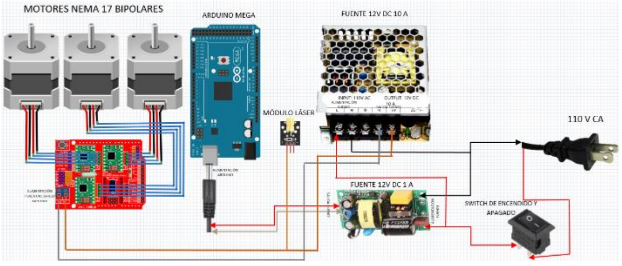


Figure 6 Connection diagram of the laser engraving system
Source (project contribution, unpublished)

Laser engraver prototype control.

The Nema 17 stepper motor used in the laser engraver prototype has an axis of 5 mm in diameter by 20 mm long and for each step it advances 1.8 degrees, where it is necessary to make 200 steps per turn.

To transmit the movement of the motors to the shaft structure and generate displacement, a mechanism was used that consists of integrating a GT2 toothed pulley with 20 teeth and placing it in front of a toothed belt 6 mm wide and 1.38 mm high for the same type of toothed pulley with a tooth height of 0.75 mm, based on Figure 7.

Figure 7 Dimensions of the GT2 20T sprocket given in mm
Source (project contribution, unpublishe)

Having the information of the stepper motor rotation ratio and its linear displacement, an algorithm was developed to generate the necessary movements to write the words MECATRONICS TESJI, the movements are on the X and Y axis, in addition to controlling the intensity of the laser beam of the laser module by means of pulse width modulation, Figure 8 shows the flow diagram that follows the logic of programming.

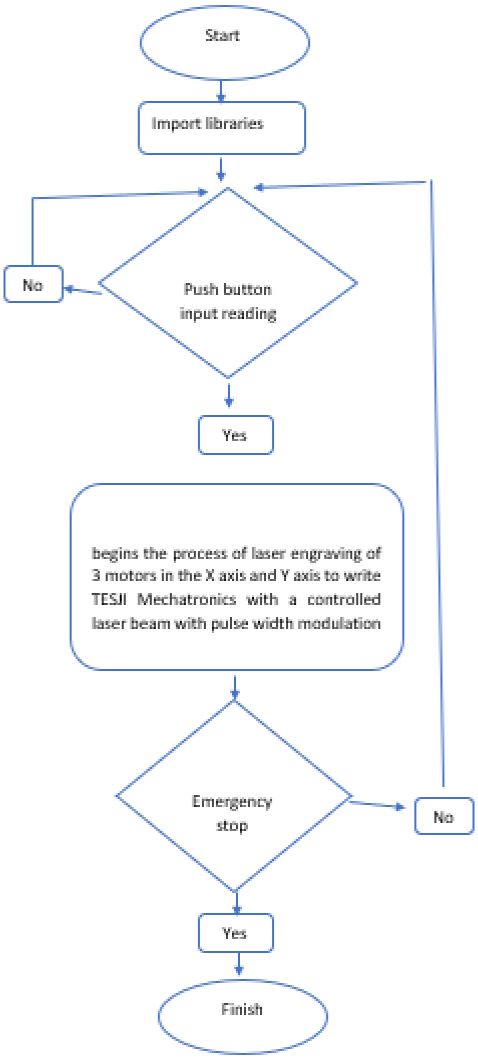


Figure 8 Programming flow chart of the laser engraving system
Source (project contribution, unpublished)

Material tests on the laser engraver

Tests were carried out on different materials to determine the power of laser engraving, using a semiconductor laser module of 1000 mW power and a wavelength of 450 nm. Figure 9 shows the engraving process on 3 mm thick MDF, the material burns accurately without imperfections, and it is a material that has a certain degree of rigidity and flexibility.

Figure 9 Etching test on MDF
Source (project contribution, unpublished)

Another test that was performed was on pine wood, as shown in Figure 10, this test shows certain defects in the recording, due to the properties of the material that is more resistant to incineration, so that in some lines it is not possible to record with adequate precision for visibility.

Figure 10 Pine wood test
Source (project contribution, unpublished)

Laser engraver performance tests

The prototype has been subjected to performance tests over time, so engraving tests have been performed every hour for 5 hours being 25 attempts each hour, in order to know the stability of the system, in addition to knowing the error rate presented in a continuous time, yielding the results captured in Table 1 of performance tests where we obtain a 95.2% final accuracy of the prototype.

Test number	**Weather**	**Type of Error**		Percentage of accuracy per test
		Laser head location errors		
1	Hour 1	0	100%	100%
2	Hour 2	0	1	96%
3	Hour 3	0	1	96%
4	Hour 4	0	1	96%
5	Hour 5	1	2	88%
Final prototype accuracy				95.2%

Table 1 Performance tests
Source (project contribution, unpublished)

System improvements and final characterization

Once the tests were carried out, improvements were identified that could enhance the performance of the system. One detail that was improved was the fixing system of the frame where the engravings are made, this was achieved through CAD design and machining as shown in Figure 11.

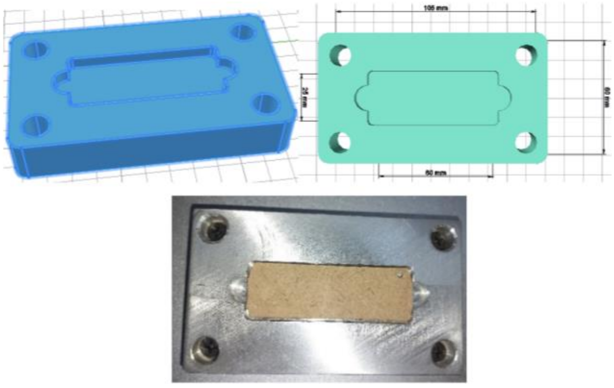


Figure 11 Frame base design in CAD software and final machined part in aluminum
Source (project contribution, unpublished)

We also designed and manufactured the frame holder shown in Figure 12, the height is 150mm to allow 50 recording frames to be placed and the width allows the frames to enter freely without damaging them, it was made of 3mm thick acrylic.

Figure 12 Frame holder design in CAD software and final piece machined in acrylic
Source (project contribution, unpublished)

Finally, a 6mm thick acrylic key ring holder was developed, as shown in Figure 13.

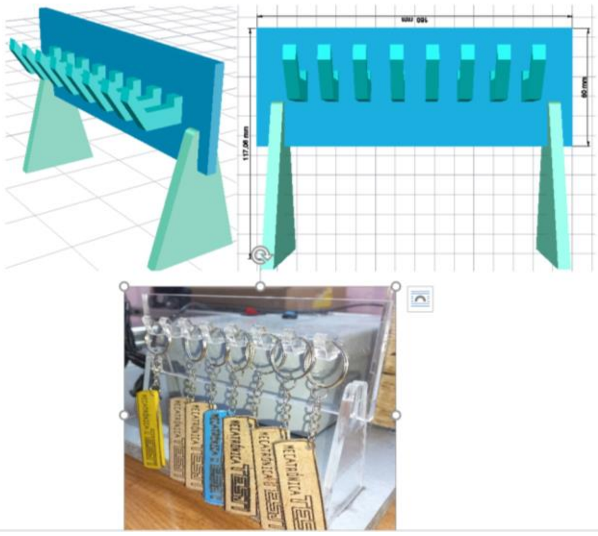


Figure 13 Key holder design in CAD software and final part machined in acrylic
Source (project contribution, unpublished)

Results

Once the improvements to the system have been made, the final characterization of the laser engraver prototype is shown in Figure 14.

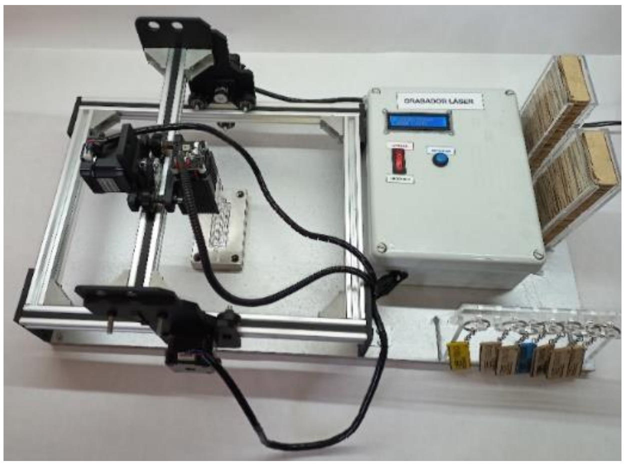
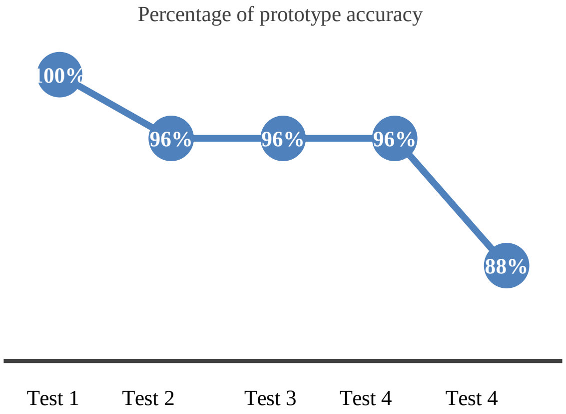


Figure 14 Final characterization of the laser engraving system
Source (project contribution, unpublished)

Considering the tests performed, Graph 1 shows the percentages that occurred during the performance tests and the time interval in which they occurred.



Graph 1 Percentage of accuracy of the prototype
Source (project contribution, unpublished)

As a result of the analysis of the tests performed, an accuracy of 95% was obtained, in addition to proving that the longer the continuous operation time, the more errors it tends to present in its operation, due to the fact that the controllers and the work tool may overheat and thus anomalies may occur in its performance.

Conclusions

By implementing this prototype, it was possible to develop a microcontroller-assisted control system for a laser engraving prototype for non-metallic materials.

It was observed that the time to perform the engraving processes varies according to the material to be used, although the recommendation is the use of MDF where a complete process takes about 2 minutes and 15 seconds; in one hour, the prototype is capable of performing up to 27 processes. When taking the results of the tests and to obtain the highest efficiency and precision of the prototype, it is necessary that after every 60 minutes of work, the prototype has at least 30 minutes of rest, this also based on what is recommended in the data sheets of the DRV8825 controllers and the working tool.

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