Design and Development of Laser Engraving Machine

Evgenija Divitarova[1], Andrijana Bocevska[2]

[1,2] *University St Kliment Ohridski, 1Maj nn, 7000 Bitola, R. North Macedonia*

divitarova.evgenija@uklo.edu.mk; andrijana.bocevska@uklo.edu.mk

Abstract:
Hands-on laboratory instructions are essential to improve the student learning feature in engineering education. In the area of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM), Computer Numerical Control (CNC) machines with their significant cost limit the accessibility of machines to the students. In this paper, a low-cost, Build-Your-Own (BYO) two axis (X and Y) vertical Computer Numerical Control (CNC) prototype is developed using off-the-shelf components, stepper motors with drivers, Arduino open-source microcontroller, and open-source motor control software. The machine provides better access and insights to the students for easy operation as well as the capability to do various sophisticated precision engraving, whether for practical or artistic purposes.

Keywords: Laser, CNC, LaserGRBL, engraver, G-code, Arduino

1. Introduction

CNC engraving is a process where computer-controlled machine tools etch or carve designs, letters, or patterns into a surface. CNC stands for Computer Numerical Control, which refers to use a computer to control the movement and operation of the machine. In the case of CNC engraving, a design is created in a software program. This design is then translated into a language (commonly G-code) that the CNC engraving machine can understand. This code directs the machine where to move and how fast to go, among other things. It's a subtractive process where the machine uses rotating cutters, or burrs, to cut away material to create the desired shape. CNC engravings are of two types: CNC milling engraving and CNC router engraving [1].

Laser engraving can be considered a type of CNC process where a CNC laser engraver uses a laser beam to create text or designs on various materials. It's a non-contact process that uses a powerful laser beam to cut or etch a design into a material. Laser engraving is a popular method for creating intricate designs on metal, plastic, wood, and other materials. The light beam used in the process is highly concentrated and precise so that the design can be detailed and intricate.

The CNC laser engraver is the main tool used in the process. It contains a computer-controlled laser module/head, the source of the focused light beam. The laser engraving process is fairly straightforward. First, the material to be engraved is placed into the laser engraving machine. Then, the computer-controlled laser module traces the design onto the surface, burning away material from the surface to create the desired design. In addition to its accuracy, laser engraving is a fast and economical way to add a personalized touch to items.

The goal is to come up with an in-house solution or create your own, Do It Yourself (DIY) design, development, and testing of laboratory equipment and systems. Therefore, low-cost, desktop and small-to-medium sized CNC machines such as mills, lathes, routers, and laser and plasma cutters can be built with an open structure so that the construction of the machine is clear and understandable to the students. The cost of the machines may be minimized by using inexpensive yet sufficiently powerful off-the-shelf stepper motors and servomotors with motor drivers. Legacy controllers can be replaced with PC-based control systems with low-cost data acquisition cards and sensors.

Lasers can have different types based on the gain medium they use. This gain medium also dictates the optical power of the laser. Commercially, the following three types of laser engravers are common [2]:

- Fiber Laser Engravers - are the type of solid-state laser with fiber optic as the gain medium.

They have a wavelength between 780 nm and 2200 nm, which is readily absorbed by most materials, even metals. They are the most powerful laser engravers on the market and are commonly used in metal engraving needs.

- CO2 Laser Engravers - have optical power which can be as low as 40W and go up to hundreds of watts. Their wavelength being close to 10,600 nm is absorbed by most materials but reflected by metals. They are not the preferred choice for metals but excel at non-metals engraving and cutting.
- Diode Laser Engravers - one of the lasers that is commonly used in desktop and hobby laser engravers. They may not be as powerful as CO2 or fiber lasers, yet they are compatible with a wide range of materials for engraving. As another benefit it can be mentioned that they are largely less priced compared to the other two lasers.

The fundamental goal of this paper is to discuss the process of designing and developing a low-cost, Build-Your-Own (BYO) two axis (X and Y) vertical laser engraving machine which is convenient to control by the Arduino CNC. The prototype is developed using off-the-shelf components, stepper motors with drivers, Arduino open-source microcontroller, and open-source motor control software and can be used to engrave designs on wood. The rest of the paper is structured as follows. Next section discusses related works, whereas the design on the laser engraving machine and the adjustment of the engraving parameters are described in Section 3 and Section 4, respectively. Section 5 offers an overview of the obtained results, and we provide concluding remarks in the last section.

2. Previous work

A technique used to develop a low-cost CNC laser engraving machine capable of engraving 2D images on materials such as plastic, wood, paper, etc. is proposed by [3]. They used the Benbox software to provide images and control the hardware's operation. The research done in [4] has focused on the design and fabrication of CNC engraving machines based on open-source electronics, with an emphasis on cost-effective solutions and specific applications such as wood engraving and milling. The importance of the machines lies in their ability to provide efficient and precise engraving solutions for a variety of materials, reducing errors and improving speed compared to manual engraving methods. The aim of [5] is to design a compact, cheap and low power CNC Laser Engraver that is also easy to operate in order to reduce complexity, cost and manual work. Their laser engraver uses the open source LaserGRBL software and can engrave onto surfaces like wood, Acrylic or plastic. The paper [6] discusses the design and implementation of two-dimensional CNC router which can engrave 2D & Gray scaled images or pictures with help of high watt burning laser module on surface which can be a paper, wood, leather, plastic or foam. A technique used to design and develop a CNC Laser Engraver and 2D Plotter (all-in-one machine) is proposed in the paper [7]. The specialty of this machine is that the user can change the tool easily whenever they want to perform many operations such as engraving an object and can also produce a 2D drawing for a particular object in A5 size sheet. Both laser engraver and 2D Plotter respond to G Codes which can be generated by the software. Research project presented in [8] is carried out for the purpose of fulfilling the following two objectives: Design and mechanical fabrication of a laser engraving machine, following the 2-axis structure; and Building program to control the engraving machine according to the design drawings. The machine can work on many different materials such as mica, wood, cloth, fruit peel, etc. The study [9] addresses issues in CNC operator training and shows how the open-architecture control system may be used in practice on a homemade 3-axis mini-CNC machine. The CNC machine tool described in the article is intended mainly for instructional purposes, it is inexpensive to build and requires just a single computer that is compatible with CNC software. A low-cost laser engraving machine to engrave plastics, acrylic, glass, wood, cardboard, and leather is the aim of [10]. The authors have found that this laser engraving process has a higher precision and accuracy as compared to traditional embellishing and embossing. CREO 2.0 software is used for the 3D modeling and simulation of the machine. Arduino and different controller boards are tried and used in assembling the machine in less time. The final assembly is experimentally verified which is based on a 2D gantry that is mounted with a laser LED payload for laser engraving on various compatible materials.

3. Design of the Laser Engraving Machine

Over the last decade, we are witnessing significant advances in laser engraving technology. Consequently, woodworking, furniture production and craft industries have seen an increase in the significance of CNC wooden laser engravers. The components of a laser engraving machine are shown in Figure 1. This machine uses a power-laser beam od 1.5W to engrave the material controlled by computer numeric instructions. The machine can be applied for photo engraving, letter cutout, name and logo personalization. This machine is designed to make the laser engrave in wood having an Arduino and the LaserGRBL software as machine automation basis. Arduino is today's most popular open-source hardware prototyping platform. Arduino receives the G-Code over serial port from the G-code interpreter and sender utility tool running on PC and gives the actuation commands to the stepper motor controller. The G-code program is loaded into the Arduino microcontroller.

Figure 1: Component of the Laser engraving machine

The technique uses the LaserGRBL software to make the process easy [11]. LaserGRBL software is a popular choice for controlling CNC laser engravers due to its versatility and user-friendly interface. It provides features such as file importing, image editing, laser power control, speed settings, and more, all available via a user-friendly interface. Users can often modify settings, adjust parameters, and enhance the software to add new functionality.

This 2D engraving machine utilizes two stepper motors for the X and Y axes (since the laser focus is manually adjusted it was not necessary to set Z). This CNC laser engraver machine is used to engrave desired designs on wood. First, it is necessary to choose an image from LaserGRBL software or design your pattern in software. Arduino passes the signal from the software to the CNC shield. CNC shield operates the drivers as per the signals and moves the motor as per the requirements. The constant laser beam engraves the material, with adjustable intensity controlled by software. Here, software does all the work such as tracing the vector image on board, maintaining the speed of drivers, etc. Hardware model of CNC laser engraver is shown in Figure 2.

Figure 2: Hardware model of CNC laser engraver

4. Adjusting the parameters for engraving

Depending on what we want to be engraved or cut, adjustments must be made to the engraving parameters, Figure 3. If we are engraving an image, it is it is necessary to transform it into black and white. For this purpose, LaserGRBL software offers several options. According to the needs of the client, Brightness, Contrast, White Clip can be are easily adjusted. There are three options for Conversion Tool (Line to Line Tracing, 1bit BW Dithering, Vectorize). We then choose the direction of engraving the image (Horizontally, Vertically or Diagonal).

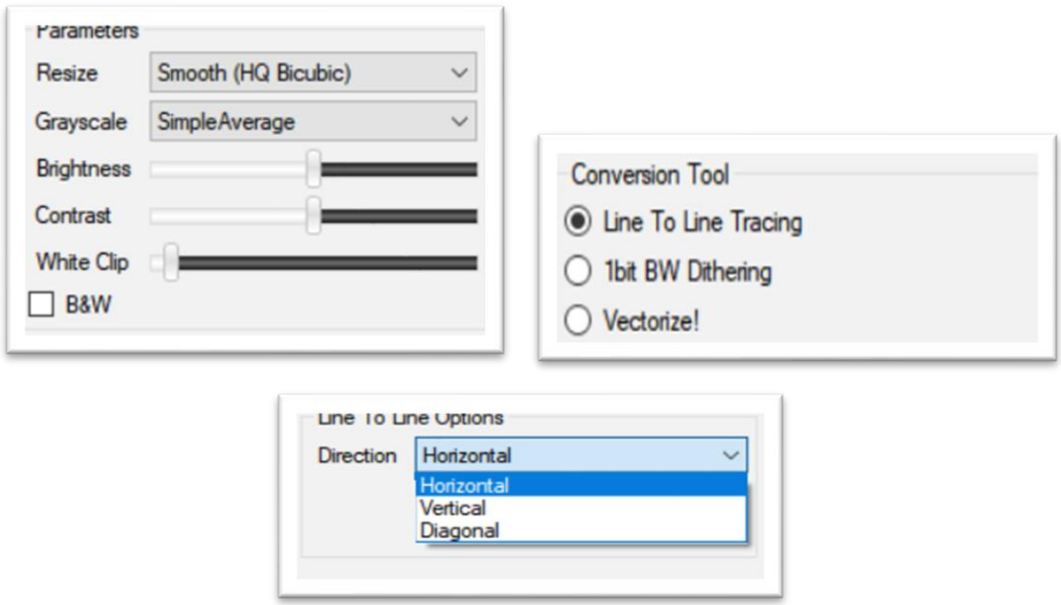

Figure 3: Adjusting the parameters for engraving

Before using a laser engraving machine, it is crucial to test three major controls in the window Target image that influence how the engraving looks: lines per mm, engraving speed, and power level, Figure 4. Properly setting this controls ensures the depth, clarity, and efficiency of the engraving and cutting. Setting the speed and power too high or too low can result in a shallow engraving, blurry results, or even burning the material.

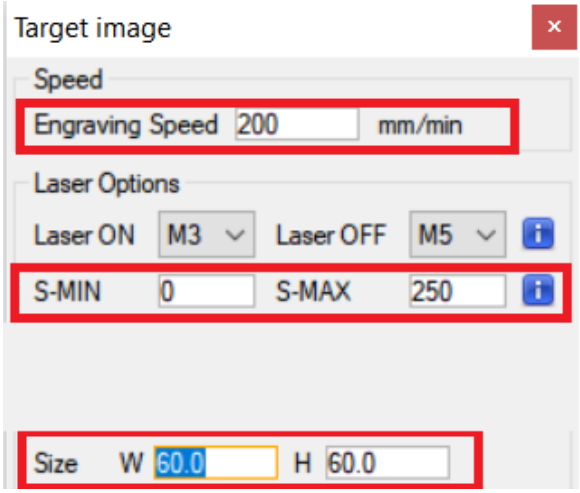

Figure 4: Adjusting the controls in the Target image window

The most important part of a laser engraver is the laser. For the laser to achieve the ultimate precision and accuracy, the focal length must be adjusted to the thickness of the material you are engraving. Proper focusing ensures the energy of the laser beam is concentrated on one point resulting in an accurate high-quality effect. Improper focusing will result in unclear, uneven, or no effect at all.

After the image is selected and the laser engraving settings are configured, the engraving process begins. The software informs us of the engraving completion time, which is determined by the material, power settings, and design complexity. After the start of the engraving process, LaserGRBL software allows the progress to be followed and stops it on an emergency basis if needed.

5. Results

In this section, the results obtained through engraving onto the surfaces are observed. The original images are shown on the left, and how they were engraved on the right on Figure 5. The outcome acquired is a wonderfully engraved complex and an exact picture that is modified to the requirements and fulfilment of the user. The surfaces used are wood, as a solid, natural material known for its durability and unique aesthetic appeal. Different types of wood can have very different characteristics when it comes to laser engraving. The results obtained are exact same to the design provided in LaserGRBL software. While it may not be as straightforward as traditional printing, the advent of laser engravers has made this process much more accessible. This type of small machines reduces the problem of maintenance and can be easily installed at a low cost.

From the results we can conclude that laser engraving stands out as a superior method for transferring images to wood when compared to alternative methods due to its precision, durability, consistency, and versatility. It allows for the creation of highly detailed and permanent images that are resistant to wear and environmental factors. Additionally, laser engraving is clean, safe, and efficient, offering significant control over the engraving process without the need for direct contact with the material, thereby minimizing the risk of damage. While the choice of image transfer method may depend on project specifics and personal preferences, laser engraving is often preferred for its high-quality results and ability to replicate designs accurately across multiple pieces.

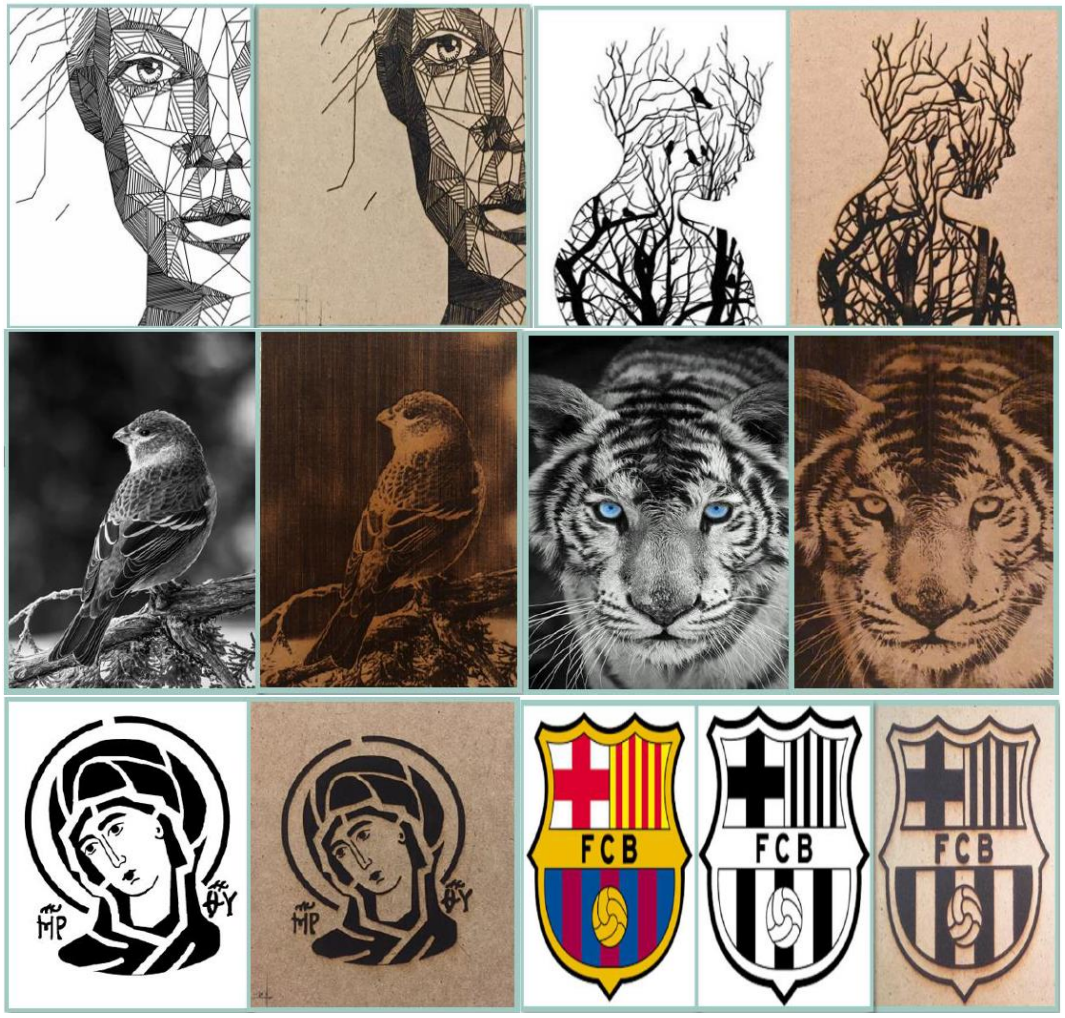

Figure 5: The original images are shown on the left, and how they were engraved on the right

6. Conclusions

This paper discussed the design and development of a laser engraving machine which is convenient to control by the Arduino CNC to engrave desired designs on wood. We can start by choosing an image from Benbox software or by designing a custom pattern in software. Arduino passes the signal from the software to the CNC shield. The CNC shield operates the drivers as per the signals and moves the motor as per the requirements. The constant laser beam engraves the material, with adjustable intensity controlled by software. Software does all the work such as tracing the vector image on board, maintaining the speed of drivers, etc. It is accessible and perfect utilization for small and medium scale industries. The results indicate that laser engraving is a superior method for transferring images onto wood compared to other techniques, thanks to its precision, durability, consistency, and versatility. Using this type of CNC laser engraving machine, users are able to add personalized touches such as logos, photos, and artwork. By offering greater personalized experiences, a wider customer and boost revenue can be attracted. The combination of a compact design, plug-and-play features, clear instructions, user-friendly software, and technical support makes CNC laser engravers relatively easy to install for users at different skill levels. The precision of CNC laser engraving machines ensures that designs are accurately engraved onto materials, resulting in high-quality finished products. Also, the automated nature of CNC laser engraving machines allows for quick and efficient production.

As efficient and precise as laser engraving machines are, they are not without their limitations. Understanding these limitations is essential to maximize the efficiency of these machines and achieve the desired results. Thus, our further work would be aimed at enhancing the functionality of this machine and expand the range of compatibility of different materials, namely:

- Upgrading the laser that would allow working with a wider range of materials,
- Adding a rotating axis that enables the engraving of cylindrical objects,
- Adding sensors i.e. limiters (in case of a problem with the gcode and a machine moves beyond the defined range of the physical limits of its motion mechanism),
- Expanding the work area to be able to create projects with larger dimensions,
- Design and components replacement with better and more precise stepper motors, changing the construction to be lighter and easily portable.

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