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DISPLACEMENT SYSTEM IN THREE CNC COORDINATES FOR WELDING TABLE WITH ACTIVATION BY ARDUINO®

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Abstract. *This work consists of developing a project with Arduino control, for a CNC coordinate table. The ease of language domain and the vast application of this microcontroller facilitated the process of choosing this device to meet the Problematics pointed out in this work. To do so, it was necessary to interpret the appropriate codes, check the compatibility of the hardware employed in the project, through the datasheet of each peripheral. In addition, the entire part of the connection and command of the table was developed, using free software, such as GRBL control, which contains a system of interpretation of the numerical Command language (G-code), so we could run the control of the table by sending commands Code-based G. The Arduino has complied with us satisfactorily in the application of the control and command of the CNC coordinate table, for automated MIG/MAG welding processes. This will enable better observation of the results, better recognition of parameters and magnitudes involved in the process, and a better evaluation of the automatic welding process as a whole, enabling for example, checking the control of the risk factors to which the Workers are exposed, such as CO and CO₂-gas content checks, improve the parameters and still prevent students, teachers and collaborators from the institute directly exposed to the rich inherent in this type of process.*

Keywords: *Arduino, welding, microcontroller, coordinate table.*

1. INTRODUCTION

With the advancement of technology, man is being replaced frequently by machines, where they perform the function that was previously attributed to the manual service. This automation and mechanization characterize the new models of industrial production in the contemporary age.

One of the industrial areas that comes in communion with this technological growth is welding. Several mechanized and automatic methods for welding are already widely used in the industrial field, such as MIG/MAG processes, submerged arc, for example. Welding with these characteristics tend to present high productivity, efficiency and quality, not for less have been highlighting each day.

In this sense a displacement system was developed in three coordinates for a MIG/MAG welding workbench, for academic purposes, with an Arduino activation, in order to bring students closer to new industrial trends. The displacement is possible through open networked software that uses language in Computerized Numerical Command and transfers the coordinates of the drawing to the Arduino and it sends pulses that cause the drivers to move the welding head.

2. JUSTIFICATION

This work is justified by its relevance in the application of new technologies that abandon manufacturing processes based on direct human intervention, minimizing errors generated by lack of attention, fatigue, repetition and malpractice, with more productivity and process quality. Where we must also take into account that industrial activities expose workers to several types of risks that are not always recognized or controlled, generating the need for periodic technical analysis in compliance with legal requirements (Ordinance No. 3.214 / 78, NR-9, MTb). The recognition and management of risks prevent financial losses and, mainly, damage to the health of the employee, since properly controlled, the potential of occupational diseases and accidents at work are reduced. In this way, this work seeks an alternative that aims to mitigate and/or minimize these risks generated during the MIG/MAG welding activity.

The Arduino platform is an incredibly didactic tool that has infinite possibilities of use. Its understanding is not complex and allows the user to create several interesting projects, adding knowledge and value to the user. Automated devices have a growing exponential deployment in the industry, this makes use of methodologies based on autonomous and semi-automated electronic controls. These devices, combined with computational languages, create exceptional tools that can be used in a wide variety of industrial processes.

We can observe these tools in a variety of industry segments, from large semiautonomous mining machines to robotic arms in the automotive industry. It is a fact that the mechanics professional can not abstain from purely mechanical systems, his knowledge has to be expanded also to electronic and computerized devices, since this is a trend without a return, which tends to expand in the market as a whole, with the increasing advancement of technology. With this in mind, this work is characterized as one of these possibilities of automation, these studies contribute to the technological enrichment and incentive to the research on the development of automated equipment of mechanical systems, adding value to the equipment, extending its possibilities of operation and minimizing the risks to the operator, teachers, students and professionals of the institution.

3. CONTROLLERS

According to Pazos (2002), the controller is understood as the electronic, mechanical, or combination device of both that aims to control a system. In general, it is responsible for generating the excitation signal $u(t)$, whatever the physical magnitude of that signal, which will produce a desired $y(t)$ response within the technical specifications.

In general the digital controllers do not have an external input reference signal but it is established by a software or peripheral device where the variations and information are determined by the control program or introduced by the user through peripherals such as a mouse, for example (PAZOS, 2002).

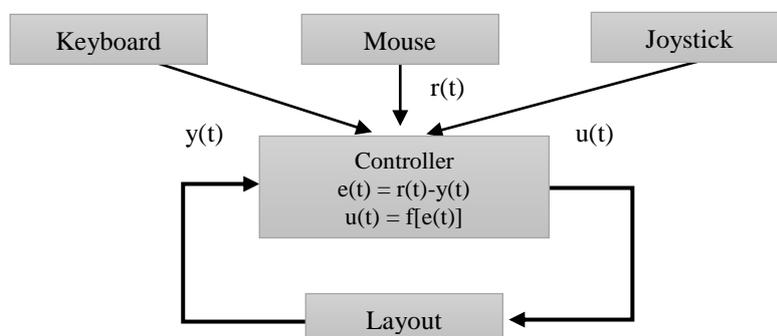


Figure 1: Digitally controlled systems. Source: Author.

4. ANALOG SIGNALS AND DIGITAL SIGNALS

According to (PAZOS, 2002) "An analog signal is a signal of any physical quantity that behaves as a continuous function in time." In turn digital signals, "are functions that, over time, can only acquire two arbitrary values". Which are generically termed 0 and 1 independent of their amplitude. We have as an example a physical quantity of digital signal the presence test of an object, here we only have two possible results.

5. SENSORS AND ACTUATORS

By definition, (PAZOS, 2002) "is a device that translates an electric energy into some other type of energy, such as: motors, resistors, lamps, pistons, electromagnets, etc. Some actuators need an analog electrical signal to operate, this is the case of DC motors whose speed of rotation is proportional to the electrical voltage delivered. As there are actuators that require analog signals to function, there are devices that demand digital signals, such as electromagnets. In this way we have by definition, analog actuators and digital actuators respectively.

Already the sensors, or transducers have a definition opposite to the actuators. For Pazos (2002), "sensor is a device that delivers an electrical signal proportional to a measured physical quantity. There are sensors for: temperature, pressure, flow, current, torque, force, speed, proximity, luminosity, etc. Where most of these non-analogical physical quantities, which leads us to define that if the processor is digital it will be necessary to use a signal converter (A/D) in its input, with some exceptions, as is the case of the presence sensor, which is a digital physical quantity, and delivers the signal directly. The presence of sensors in automated systems has great importance and this system is characterized as intelligent system.

6. INTERFACE

In order to introduce or extract electrical signals from a processor, it is necessary to use circuits called interfaces, which can be output or input. These interfaces are constituted by an electronic system called latch (PAZOS, 2002).

(PAZOS, 2002) Latch is a circuit capable of storing for an undetermined time an existing data in its input line, as well as a memory of 1 bit. Physically they are built with flip-flops and aligns control that enables the storage of the data that is called a gate or strobe, through so select where the result is available on the microcontroller bus.

7. DRIVER

According to Pazos (2002), "A driver is a digital circuit that amplifies a signal of low power, allowing to activate or deactivate a digital actuator, that works with greater levels of energy than the interface of exit".



Figure 2: The driver function. Source: Author.

For control systems that have a 0V to 5V output interface, we can use a simple transistorized driver, this driver uses an ON/OFF control.

8. MICROPROCESSER

Imagine a cake recipe made by a cook. The recipe is equivalent to a cake-building software, which may be written into a cookbook, which is our Read Only Memory, read-only memory ROM. The recipe in turn must be read and executed step by step, paying attention to each item and subitems, "Subroutine" of the recipe (software). Basically this is what a Microprocessor should do.

When we need to add ingredients, or larger quantities, or adding new elements to the recipe, we need a scratch sheet, "Microprocessor RAM", Random Access Memory. It is in her that we do the temporary calculations, which we later throw away. It is possible to check in this example in a brief way the operation of the Microprocessor, which in this case is the cook, which obeys what is written in the recipe book, Memory ROM, and uses drafts for temporary calculations, RAM. The material, the cook, the cookbook, and the leaves of the draft

book are part of the system hardware, the interpretation and execution of what is written in the book is carried out by the Microprocessor-Cook (NICOLOSI, 2007).

Thus, we can define that a Microprocessor is an electronic element, developed to perform specific tasks, with a specific command language, that uses a Code Memory (ROM) to "read" the instructions to be executed and uses a Data Memory (RAM) to temporarily store instruction-specific information for as long as that information is stored.

9. ARDUINO MICROCONTROLLER

Wikipedia (2017) states that "An Arduino is a single-board microcontroller and a set of software to program it. The hardware consists of a simple free hardware design for the controller, with an Atmel AVR processor and built-in input / output support. The software consists of a standard programming language and the bootloader that runs on the board. "In practical terms, an Arduino is a small computer that can be programmed to process inputs and outputs between the device and the external components connected to it. According to Roberts (2011) Arduino is what we call a physical or embedded computing platform, that is, a system that can interact with its environment through hardware and software.

The Arduino concept arose in Italy in 2005, with the aim of creating a device that would be used in projects and prototypes constructed with less cost compared to other systems available in the market (RENNA et al., 2016). The biggest advantage of Arduino over other microcontroller development platforms is its ease of use and learning. The Arduino can be used in several designs, together with its Shields, which are printed circuit boards normally attached to the top of the unit through a pin-plug connection such as: independent interactive objects, manipulation of motors, wireless network.



Figure 3: Block diagram of a processing chain using Arduino. Source: Author

To program the Arduino (make it do what we want) we must use Arduino's IDE (Integrated Development Environment), a free software, none of which we write the code in the language Arduino understands (report in C and C ++). The IDE allows you to write a computer program, which is a set of step-by-step instructions, in which we upload to the Arduino.

It is based on a microcontroller board, with I/O accesses, on which were developed libraries with functions that simplify their programming, through a syntax similar to those used in C and C ++ languages. Its main technical specifications are set out in the table below.

Table 1: Reference Characteristics of the Arduino Uno. Source: Arduino.

Characteristics	Reference values
Microcontroller	Atmega328P
Operating Voltage	5V
Power supply voltage (recommended)	7-12V
Power Voltage (limit)	6-20V
Digital I/ O pins	14 - of which 6 may be PWM output
Analog input pins	6
Direct current I/ O	40 m
Continuous current for pin 3.3V	50 m
Flash Memory	32 KB - 2 KB are used for bootloader

10. SCREWS AND STEPS

In many applications the drive bolts are often used to turn a rotary motion into a linear motion. In the case of this project was used three sets of tortoise as a linear motion driven by three DC electric motors (PAZOS, 2002). This system consists of a cylindrical threaded shaft coupled to an axis of an engine, a female threaded part

of the same type, which is threaded on the shaft, this part has a guide to prevent rotation during movement. This way when the threaded shaft rotates driven by the motor, the part will be unable to rotate because of the guide, it will advance or retract in accordance with the direction of rotation described by the motor. Drive bolts have the great advantage of reducing the speed, even more precisely than toothed drive drives, in addition to allowing greater precision in the positioning of the part.

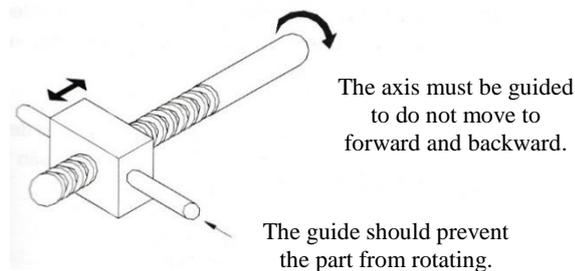


Figure 4: Threaded shaft and screw. Source: Pazos.

11. DC MOTORS

One of the main devices used in automated systems is the electric motor, this equipment is present in the most varied machine tools, such as, Lathes, milling machines and CNC. The function of the DC motor will mainly be found where variable speed drives are required or where particular characteristics of the series motor are required, such as in electric traction. Traditionally, quadrant drives, with both speed and torque control, are provided through Ward-Leonard systems. This system is the oldest and was introduced in the late 1890s. It consists of the use of an auxiliary motor-generator (MG) assembly which is responsible for supplying the terminal voltage of the motor whose speed is to be controlled, the motor drives with constant speed of a direct current generator, by varying the field current of this Ifg generator, the terminal voltage V_t applied to the motor C (drive) is varied, therefore varying its speed. For speed drives only AC motors must be used (LANDER, 1988).

By definition, engines are devices that transform some type of energy into mechanical energy. This mechanical energy is developed through the rotation of an axis that rotates with a certain speed and torque (PAZOS, 2002). The rotation of this axis provides movement to the plant or to some of its parts. They are basically composed of two parts. A fixed, non-moving part called a stator, which produces a constant magnetic field, either with an electromagnet or permanent magnet. The second part is rotating, and is called a rotor or armature, which has a winding assembly where the continuous electric current flows. Thus, a DC machine consists of a field and an armature, the field being excited by the DC winders, which establish a magnetic flux Φ bonded to the armature (LANDER, 1988), the field is produced by the stator.

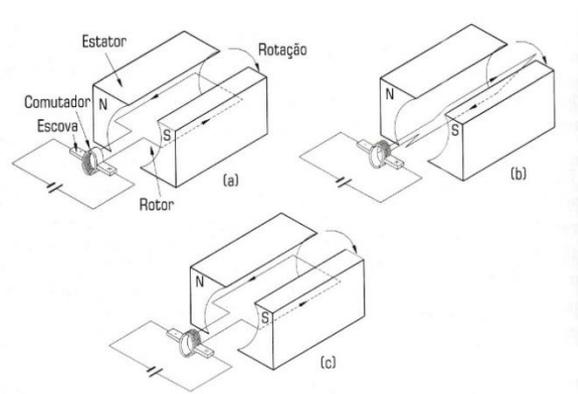


Figure 5: Principle of operation of the DC motor; Source: Pazos.

12. STEP MOTORS

Stepper motors are a particular type of motor widely used for computer peripherals, such as printers, hard disk drives, etc. This type of motor provides an output in the form of discrete angular increments, which are

controlled by electrical impulses of the power signal, where each pulse corresponds to a fixed angle of rotation. In this way, this type of motor can be used in open loop, since the controller has the possibility of knowing the position of the axis with respect to a reference, where it is necessary only to supply the amount of pulses required for each axis to rotate in a certain amount of steps.

We can observe the scheme of operation of this type of motor, which has a stator and a rotor inserted in its interior solidary with the axis of rotation. The stator has several electromagnetic poles that can be polarized according to the direction of current flowing through the electromagnets, so if the first pair of poles are activated, for example, pole 3 is north and pole 1 is the south, and then the second pair again obeying the same order for 4 and 2, the rotor will rotate 90° clockwise, performing the so-called "pitch". In practice, the rotor has two sets of poles separated into two sections along its length, where each set the poles are made up of teeth of a gear. The second set has a half-tooth displacement relative to the first. The sets may have permanent north poles and others south. The stator also has several electromagnets distributed along its inner circumference, as can be seen in the figure below.

13. MECHANISM OF ADVANCE

These motors have a direct current servo motor, which are also regulated with a pulse rectifier, these motors have high load capacity and can operate with a large field of rotation in the order of $b = 103$, the main difference is in the commutation. With a pulse inverter, the rotation is regulated through the rotor angle, over the power and the current (WITTE, 1998). In order to have a mechanism that is capable of reversing the direction of rotation and braking ability, a quadrangular drive is required.

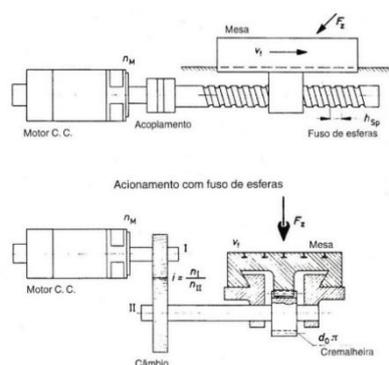


Figure 6: Basic construction of an advance drive. Source: Witte.

14. CNC MACHINES

The CNC (Computer Numerical Control) is a machine tool by numerical command, which presents a command that corresponds to the requirements of the user. In this way this type of equipment is part of the productive structure of several industries. Its characteristics are immediately recognized by its external composition, unlike a lathe or a milling machine, this type of equipment is controlled by a panel or computer that controls the machine, where it is possible to do all programming and drawing of the cutting vectors of the part. In the case of computer-controlled machines, these features are enhanced and expanded with tools for controlling and editing mechanical designs. The direction of the tool is given in the three axes, x, y and z, but can be changed in six axes, namely: x, y, z for translation and A, B, C for rotation (WITTE, 1998), we can check the numerical control elements in Appendix A.

15. EXPERIMENTAL PROCEDURE (OR COMPUTATIONAL PROCEDURE)

The project consists primarily of the programming stage, where the development of the hexadecimal language in grbl format is done. It will be inserted in the Arduino so that it receives the commands of the CNC program through grbl Controller or Universal G-code Sender software, which analogously to a CNC language software, transfers the coordinates of the drawing, vectors, in G-Code to the Arduino. This one interprets this data and sends it to the drives that does the conversion of pulses generated by the Arduino in rotation directed to the stepper motors.

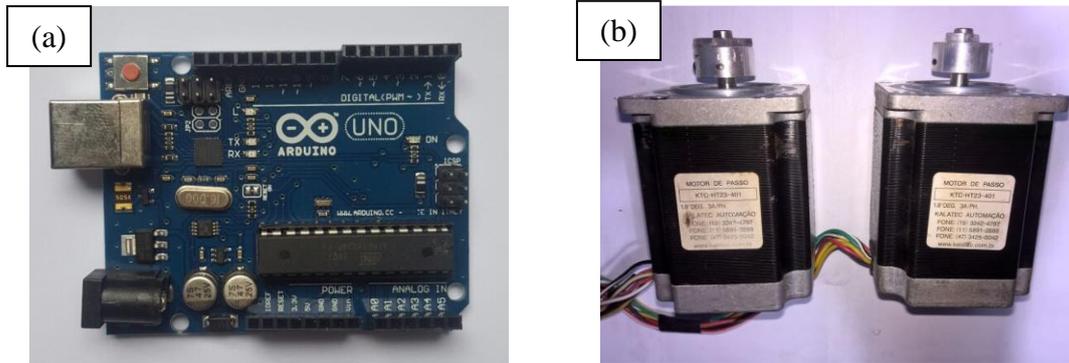


Figure 7: Arduino Uno (a), Stepper Motor HT23-401 (1,8Nm) (b), respectively. Source: Author.

After the development of the program it was made the assembly of the command CPU, where the drives and the Arduino board are allocated, with power previously raised according to the power required by the motors used in the system, in this case 24V - 110V VDC. The connection cables between the control CPU and the step motors were also made. Finally, the command and system tests were done, basically consisting of the following steps to make the Arduino understand the CNC language and transfer the command to the motors that will move the stands:

- Designing the drawing in the SketchUp program;
- Conversion of the drawing to the G-code format through an online converter that plots the vectors of the drawing;
- Upload the drawing in the Grbl Controller program that reads the coordinates and transfers the command to the Arduino, which interprets these commands and transfers them to the stepper drives.

16. RESULTS AND DISCUSSION

In view of the results obtained, a greater difficulty was found in make that an Arduino could perform a reading of the drawing and later send this command to the stepper motors. After a sequence of research, it was observed that the behavior of the table in question is very similar to the process analogous to the CNC language, so it was possible to find a free library, the Grbl.h, that allows the Arduino to understand the vector language of the CNC coordinates and execute your commands.

Added to this it was found a software, also free, that makes a reading of the drawing and sends its data to the Arduino, the Grbl Controller. In addition, other difficulty encountered in the process was the compatibility between the Arduino and the motor drives. For this, an investigation was made on the datasheets of the drives and motors to ensure their use.



Figure 8: Structure of the welding table. Source: Author.

17. CONCLUSIONS

According to what was exposed in the project, the results presented and the tests performed, it was concluded that the automated control via Arduino for a CNC coordinate table was successful. In other words, it will allow a better adequacy and installation of the command necessary for functionality of the table.

By analyzing the computerized numerical control programs based on G-code and available in a network of easy accessibility it was verified that they satisfied the objective of generate de movement of a welding equipment in three coordinates, since these have compatibility with the Arduino board in their languages.

It is also reported that the electronic components are harmonic with programming systems and they execute the commands by Arduino satisfactorily.

18. ACKNOWLEDGMENTS

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20. RESPONSABILITY NOTICE

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