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VISIÓN ELECTRÓNICA

A CASE-STUDY VISION

2 DOF robot programmed with MatLab® (guide and Peter Corke) and Arduino uno for writing alphabetical characters

Robot de 2 DOF programado con MatLab® (guide y Peter Corke) y Arduino uno para escritura de caracteres alfabéticos

Angie Paola Mancipe-García [1], Nicolas David Barrera-Fonseca [2], Diego Alfonso Rojas-Sarmiento [3], Fabián Barrera-Prieto [4]

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ABSTRACT

This document presents the interaction between a microcontroller, a computer and two servomotors for the operation of the prototype of to robotic arm with 2 degrees of freedom, applied to the writing of to 2R robot which was programmed with to low-cost microcontroller (Arduino Uno), using the servomotors for the movement of the joints of the 2R robot. In addition, the work area of the 2R robot es presented, using peter Corke's robotics toolbox in MATLAB, the connections in the circuit with the microcontroller and the other electronic components that work simultaneously with the 2R robot were also made. Finally, the results obtained through points and trajectories with different modes of operation through physical and simulated tests in Matlab are presented.

RESUMEN

Este documento presenta la interacción entre un microcontrolador, un ordenador y dos servomotores para el funcionamiento del prototipo de un brazo robótico de 2 grados de libertad, aplicado a la escritura de un robot 2R el cual fue programado con un microcontrolador de bajo costo (Arduino Uno), utilizando los servomotores para el movimiento de las articulaciones del robot 2R. Además, se presenta el área de trabajo del robot 2R, haciendo uso del toolbox de robótica de Peter Corke en MATLAB, también se realizaron las conexiones que hay en el circuito con el microcontrolador y los demás componentes electrónicos que trabajan simultáneamente junto al robot 2R. Finalmente, se presentan los resultados obtenidos mediante puntos y trayectorias con diferentes modos de funcionamiento mediante pruebas físicas y simuladas en Matlab.

1 Current position: Student / University ECCI / Program in Engineering Mechatronic / Colombia. E- mail: angiep.mancipeg@ecci.edu.co
2 Current position: Student / University ECCI / Program in Engineering Mechatronic / Colombia. E- mail: nicolasd.barreraf@ecci.edu.co
3 MSc. Engineering Mechatronic, University Military New Grenade, Colombia. Current position: Teacher time complete/ECCI University/Program in Mechatronic Engineering, Colombia. Email: drojass@ecci.edu.co
4 MSc. Systems mechatronics, University of Brasilia, Brazil. Current position: Teacher time complete / ECCI University / Program in Mechatronic Engineering, Colombia. Email: fbarrerap@ecci.edu.co

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1. Introduction

The robotics industrial is a field of the engineering that occupies of the definition, design, development and manufacturing of industrial robots that automate people's work, that is, they execute their movements in a chain of manufacturing either production industrial and perform their tasks of manner further fast, precise, without rest and avoiding the danger for the people.

The robots perform tasks repetitive and dangerous with a lot elderly precision of it than people would do, achieving higher quality in manufacturing or production. To be of machines that they work without rest produce in major amount and with less cost, so the increase in productivity is exponential [1].

It is known that robotic arms are of great importance for the industrial sector, especially because they are considered an improvement in the industry at the level of production and quality [2]. The end of a robotic arm is called an end effector or gripper, which can carry out different tasks as collect, Weld, paint, position, drill, etc; this allows flexibility in industrial tasks [3].

In the article speaks mostly of robot manipulators, the which They consist of two main parts, the first is the 2R robot, which is a system composed of joints mechanical, actuators and sensors, the second is the microcontroller the which receives and processes the information to generate a final response through the 2R robot. There are different configurations of Manipulator robots depending on the type of movement they handle, which are Cartesian robot (3 prismatic movements), Cylindrical robot (2 prismatic movements and one rotational movement), Spherical or Polar robot (2 Rotational movements and 1 prismatic), SCARA robot (2 Rotational movements and 1 prismatic) and finally the Angular robot (3 rotational movements) [4]. For the project the chose the setting of a robot Cartesian with 2 degrees of controlled freedom by Arduino ONE. There is that have in account that exist 3 laws basic of the robots the which serve for the safety and integrity of humans and the robots themselves [5].

In the development of the project, the MATLAB IDE was used, which is a calculation platform. scientist and programming of high level, is an around computer scientist technical interactive for algorithm development, data visualization, data analysis and numerical analysis [6]. Which was used for programming the 2R robot, and was also complemented with the tool Toolbox for the graphing of the robot 2R in simulation [7] and the GUIDE tool to generate the Graphical Interface that the end user uses to select an operation mode [8].

To carry out the movement of each joint of the 2R robot, Direct Kinematics was used. and Reverse and in addition they made the modeling mathematicians of each a of them [9]. The kinematics direct performed to through of the method D.H. (Denavit-Hartenberg), This is based on a systematic procedure that helps establish coordinate systems for each one of the links that has the robot 2R with it which generate the DH parameters (θ, d, α, a) [10]. This method allows studying the movements of the joints of a manipulator robot of different architectures [11].

The term microcontroller uses for describe a system that includes a program memory, data memory and input-output (I/O). Some microcontroller systems include additional components, such as timers, counters, analog-to-digital (A/D) converters [12]. The 2R robot was programmed through an Arduino Uno microcontroller which serves for information processing and execution. of the modes of operation that makes the robot 2R [13]. Where to his time I manipulate two actuators in this case servomotors that they interpret both joints of the 2R robot these receive a signal from the microcontroller to move at a certain angle and together obtain the desired position of the 2R robot [14].

For finish some Applications of the robotics they can find in the bouquet industrial, military, educational, farming, space exploration, entertainment, healthcare, security, etc. With the purpose of facilitating activities where the physical integrity of people is put at risk, as well as exploring areas that would be harmful to the be human, and also for the execution of jobs repetitive of high precision the which could cause injuries to people [15].

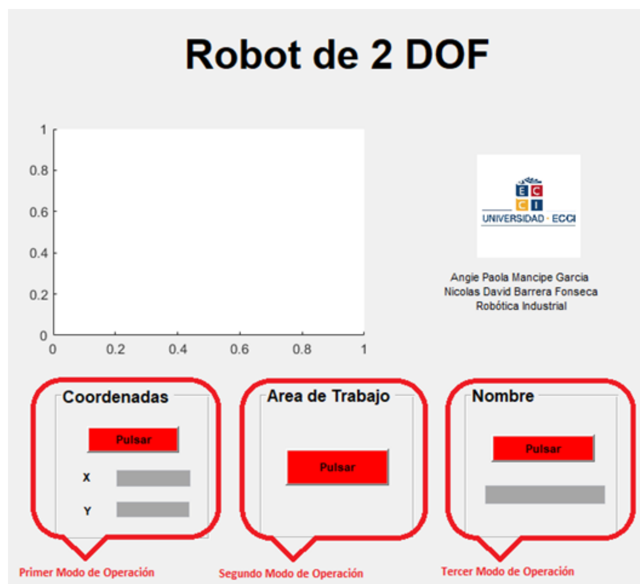
2. Methodology

2.1. Development

This research focused on industrial robotics and microcontroller programming. in this case Arduino One. use the SDI of MATLAB for the development of the 2R robot project, two tools were used which were GUIDE which is the Graphical Interface for interaction with the user, also Peter Corke's Toolbox to graph and simulate the 2R robot in real time where only linear movements were made. In the construction of the robot 2R generate relationship between a computer, an Arduino Uno and two servo motors, See Figure 1.

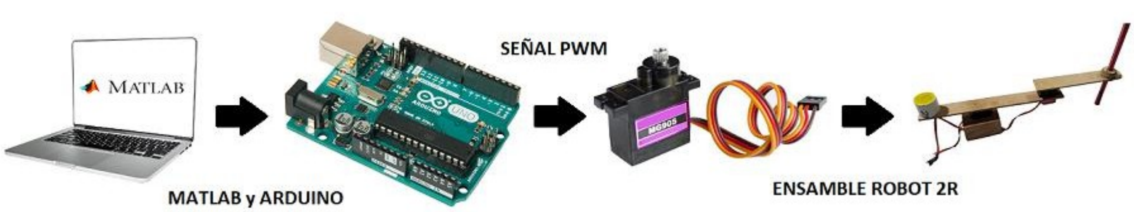
The they made three modes of operation for the driving of the robot 2R, the first mode consists of the user entering the coordinates (X and Y) where they want it to be located, since we know the coordinates further no the angles, employs the Kinematics Inverse. In it second mode of operation the user will press a button and will make the area of work of the 2R robot which will be determined by the length of the links of the 2R robot and Direct Kinematics will be used, since we know the operating angles. Finally, in the third mode of operation will write a name in a chart of text with a maximum length of 9 letters in the Interface Graph and you will see so much in simulation as in time real, in this last case Direct and Inverse Kinematics will be used to find as many positions as angles in the course of the writing of the name. See Figure 2 where the three operating modes of the 2R robot are observed.

Figure 2. Modes of Operation of the robot 2R in the Graphic interface



Source: Own.

Figure 1. Interaction between devices and peripherals.



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In addition, the flow chart for programming the code for the microcontroller is outlined.

2.1.1. Kinematics Direct 2R

It consists of determining the position (translation) and orientation (rotation) of the end effector, that is, the TCP, with regard to the system of reference. In the SDI of MATLAB this kinematics is used for graph, also acquire the coordinates x and AND of the robot 2R, this perform knowing before that nothing the angles of the joints and the length of their links.

In this case specific we will use the Method Systematic (DH), their acronym correspond to its creators who were Denavit and Hartenberg in 1955. It is a matrix method that consists of systematically establishing a final coordinate system with respect to the reference coordinate system. In order to carry out this method (DH) it is necessary to know the following series of steps:

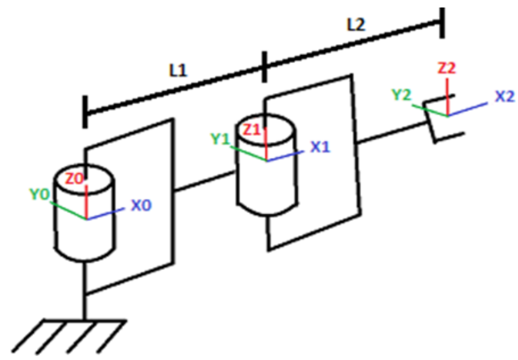
1. Assign a system coordinate for each joint of the robot.
2. Determine the parameters DH (θ, d, α, a), which will be used in Peter Corke's Toolbox.
3. Obtain the Matrix correspondent.

Also for the assignment of SC(DH) they must continue four rules the which are:

1. The Z axis must be located in the axis of rotation if the joint is rotational or in the same direction of movement if it is prismatic.
2. The X axis must be perpendicular to the Z axis of its same Coordinate System (CS) and to the previous Z axis.
3. All the systems they must respect Rule of the hand right.
4. Each axis x has to intersect the axis Z of the S.C. immediately former.

As a final piece of information, it should be emphasized that this Planar 2R robot can only be operated in a two-dimensional plane. already that No account with a height correspondent, is say only move to in the X and Y axes. Next, Figure 3 shows the Coordinate Systems of the 2R robot.

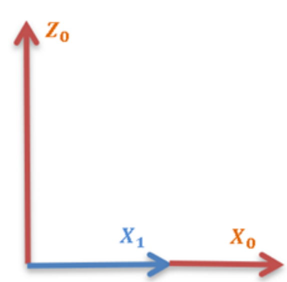
Figure 3. Systems Coordinates (SC) robot 2R.



Source: Own.

After assigning the coordinate systems, the next step is to determine the parameters DH (θ, d, α, a), since the relationship between the number of joints plus one must always be met, in this case there are three SCs. Since (SC{0}) does not have a S.C. former for find the parameter θ_1 starts from the (SC{1}) in where The previous Z axis is taken as a reference, that is, Z_0, to move the previous X axis (X_0) to the current X axis (X_1) is must add the angle that form a θ_1 and if not having said angle will be left only θ_1 as seen in Figure 4. The parameter d_1 is the distance between the S.C. current (SC{1}) and the Previous SC (SC{0}) with respect to which moves in the axis Z, i.e. $d_1 = 0$.

Figure 4. Parameter θ_1



$$\theta_1 = \theta_1 + \measuredangle(X_0 \rightarrow X_1)$$

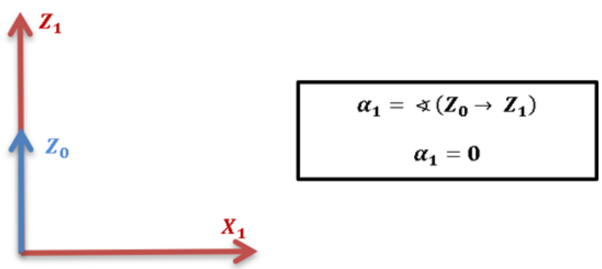
$$\theta_1 = \theta_1$$

Source: Own.

In the parameter α_1 take of reference the axis x current ($X1$) for move the previous Z axis (Z_0) to the axis Z current (Z_1) and will put the angle that form both axles, see Figure 5.

The parameter a_1 is the distance between the S.C. current (SC{1}) and the S.C. former (SC{0}) with respect to what moves in the X axis, that is, L_1 .

Figure 5. Parameter α_1



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Next, the calculated values of the first row (i_1) are written in the table of parameters and subsequently to these proceeds to carry out the same steps previous for calculate the values of the row 2 (i_2) and so place them in the board of parameters as is shown in Table 1.

Table 1. Parameters of the DH method

i	θ_i	d_i	α_i	a_i
1	θ_1	0	0	l_1
2	θ_2	0	0	l_2

Source: Own.

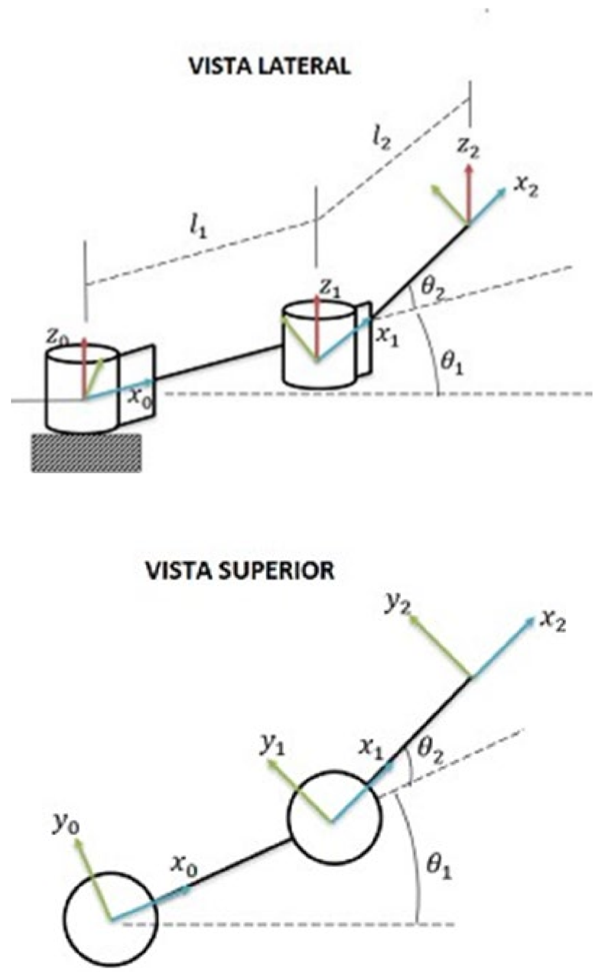
Finally, now Once the DH parameters have been obtained, they will be used for the graphing of the 2R robot in the Peter Corke MATLAB tool.

2.1.2. Kinematics Reverse 2R

The opposite of Direct Kinematics is Inverse, this consists of determining the angular and/or linear movements of the joints in this case two rotational ones through the coordinates that the 2R robot will reach in X, and Y, the corresponding angles (θ_1 and θ_2).

Taking into account Figure 6, the triangle formed by the two joints is decomposed to obtain the values of θ_1 and θ_2.

Figure 6. Views robot Planar 2R.



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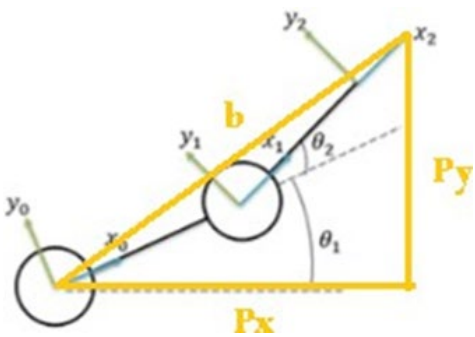
Taking into account Figure 6 (Top View) an orange right triangle can be formed that comes out respectively of the two joints the which sample in the Figure 7.

Figure 7. Triangle Rectangle



Source: Own.

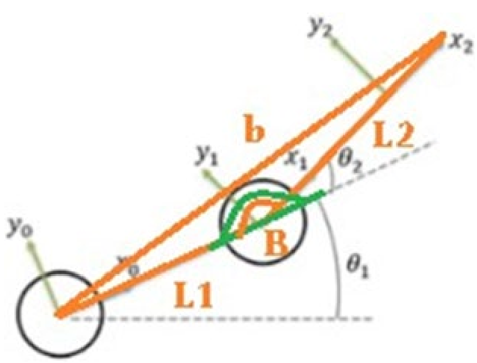
Since it is a right triangle, the Pythagorean theorem Eq. (1) is used and replaced by its corresponding values.

$$h = \sqrt{Ca^2 + Co^2} \qquad (1)$$

$$b = \sqrt{Px^2 + Py^2}$$

Already obtained the value of b proceeds to form a new triangle orange Figure 8, with the links (l_1 and l_2) and the hypotenuse b to find θ_2 using different trigonometric properties.

Figure 8. Triangle formed by b, L1 and L2.



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To continuation, will use the law of the Cos Eq. (2) for find Cos of θ_2.

$$b^2 = a^2 + c^2 - 2ac \cdot cosB \quad (2)$$

$$b^2 = l_2^2 + l_1^2 - 2l_2 l_1 \cdot cosB$$

Knowing that the angle formed by B and θ_2 is 180°, we proceed to solve for B to obtain Eq. (3).

$$180 = B + \theta_2$$

$$B = 180 - \theta_2 \qquad (3)$$

The replaces in Eq. (2) the worth of the angle B obtained previously.

$$b^2 = l_2^2 + l_1^2 - 2l_2 l_1 \cdot cos\,(180 - \theta_2)$$

With the property trigonometric Eq. (4) proceeds to rewrite the formula former.

$$cos\,(180 - \theta_2) = -cos\,(\theta_2) \qquad (5)$$

In where is left over the following result.

$$b^2 = l_2^2 + l_1^2 + 2l_2 l_1 \cdot cos\,(\theta_2)$$

It following is the clearance of the cosine of θ_2 for acquire Eq. (6).

$$cos(\theta_2) = \frac{b^2 - l_2^2 + l_1^2}{2l_2 l_1} \qquad (6)$$

As already have cosine of θ_2 it goes to use the following property trigonometric Eq. (7) for the clearance of breast of θ_2.

$$sen^2(\theta_2) + cos^2(\theta_2) = 1 \quad (7)$$

$$sen\theta_2 = \pm\sqrt{1 - cos^2(\theta_2)}$$

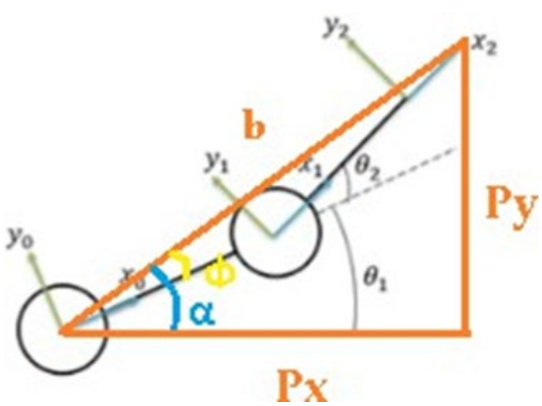
Since the result of the sin of θ_2 It is a square root, depending on the sign of the root, the 2R robot will have the elbow up if the sign is negative, it will have the elbow down if the sign is positive. Once the sine values of θ_2 have been obtained and cos of θ_2 the next thing is to solve for θ_2 of Eq. (8)

$$tan(\theta_2) = \frac{sen(\theta_2)}{cos(\theta_2)} \quad (8)$$

$$\theta_2 = tan^{-1}\left(\frac{sen(\theta_2)}{cos(\theta_2)}\right)$$

In the Figure 9 they can notice the angles α and ϕ that they will be used for find the value of θ_1.

Figure 9. Triangle formed by b, Px and Py



Source: Own.

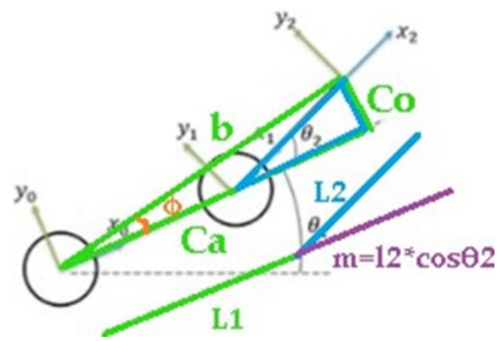
As can visualize in the triangle former the difference between the angle α and angle ϕ gives $\theta 1$. See Eq. (9).

$$\theta_1 = \alpha - \phi \quad (9)$$

Subsequently calculate the worth of α in which sample in Eq. (10).

$$\alpha = tan^{-1}\left(\frac{Py}{Px}\right) \quad (10)$$

Figure 10. Triangles formed by b, Co, AC and L2.



Source: Own.

We obtain Cateto Adjacent and Cateto Opposite of the triangle green. As You can see the Opposite Leg is the same for the green triangle as for the blue one, therefore, we replace and solve for ϕ.

$$Ca = l_1 + l_2 \cdot cos(\theta_2)$$

Find the Cateto Opposite using the following identity trigonometric Eq. (11).

$$sen(\theta) = \frac{Co}{h} \quad (11)$$

The next thing is to solve for the Opposite Leg and replace h (Hypotenuse), which in this case is l_2.

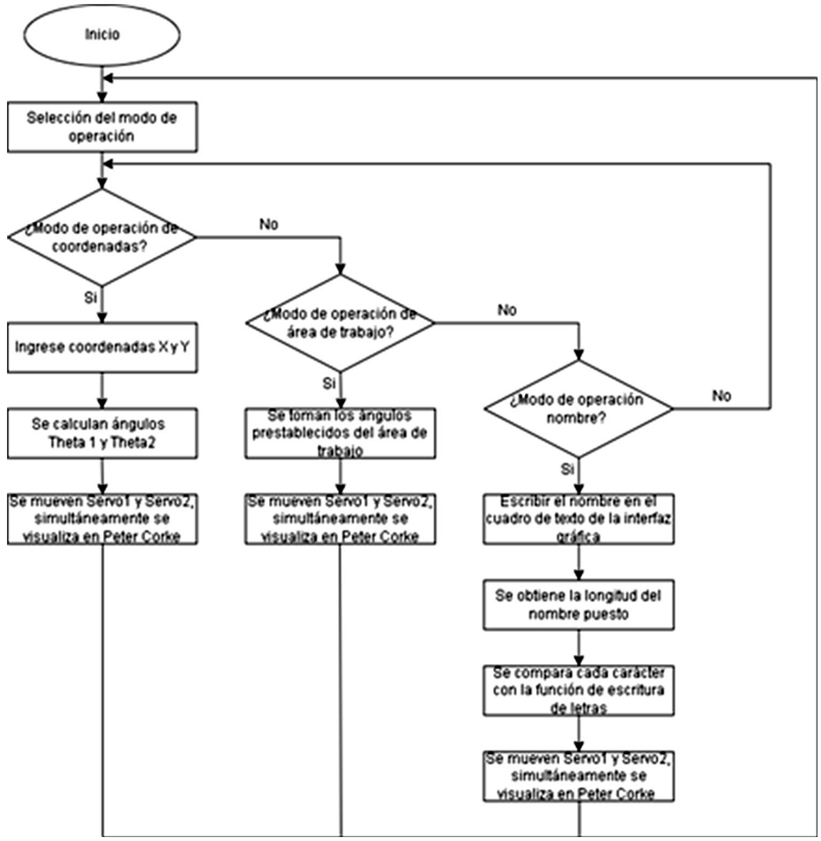
$$Co = l_2 \cdot sen(\theta_2)$$

To continuation, It will be used the trigonometric identity of the tangent and we clear ϕ, see Eq. (12).

$$tan(\phi) = \frac{Co}{Ca} = \frac{l_2 \cdot sen(\theta_2)}{l_1 + l_2 \cdot cos(\theta_2)}$$

$$\phi = tan^{-1}\left(\frac{l_2 \cdot sen(\theta_2)}{l_1 + l_2 \cdot cos(\theta_2)}\right) \quad (12)$$

Figure 11. Diagram of flow modes of operation of the robot 2R.



Source: Own.

Last, replace the values of α and ϕ for calculate the worth of the angle θ_1, see Eq. (13).

$$\theta_1 = \alpha - \phi$$

$$\theta_1 = tan^{-1}\left(\frac{Py}{Px}\right) - tan^{-1}\left(\frac{l_2 \cdot sen\,(\theta_2)}{l_1 + l_2 \cdot cos\,(\theta_2)}\right) \quad (13)$$

2.1.3. Diagram of Flow

The makes flow chart of the three modes of operation of the robot 2R.

3. Design

During the creation of the code, the measurement of the links and degrees of freedom was taken into account. of each joint, already that in base to they performed the mounting physical; So Likewise, two servomotors were used with movement from 0° to 180°.

In the Board 2 presents the amount of links and the length of the themselves.

Table 2. Measurements of the links of the robot 2R

Links	Length
Link 1	10 cm
Link 2	10 cm

Source: Own.

The materials that they used in the assembly of the robot 2R is an Arduino One for the programing, wood MDF for the creation of the links and the base, two servomotors for the joints, and a marker representing the end effector of the 2R robot.

4. Results

The operation of the 2R robot is divided into 3 operating modes: (1) Manual by coordinates, (2) Work Area and (3) Name. The selection is made by the user through the graphical interface with the Matlab GUI option, where, apart from the mode selection, the simulated position of the 2R robot in the workspace can be displayed.

In the first mode of operation, the trajectory of the 2R robot is carried out until reaching the coordinates assigned by the user as shown in Figures 12 and 13, where the MoveJ trajectory (angle interpolation) carried out by said 2R robot in simulation is presented. and in physical assembly, respectively.

In the second mode of operation, the delimitation of the work area of the 2R robot is carried out in simulation (see Figure 14) and in the physical assembly (see Figure 15), taking into account the rotational ranges of movement of each of the servomotors.

Finally, in the third and last mode of operation, the trajectory of a string of characters (e.g. name) entered by the user in the graphical interface is carried out as presented. in the Figure 16 and 17, where observe clearly the name written by the 2R robot both in simulation and in physical assembly, respectively.

Figure 12. Career in mode of operation Coordinates (Simulation)

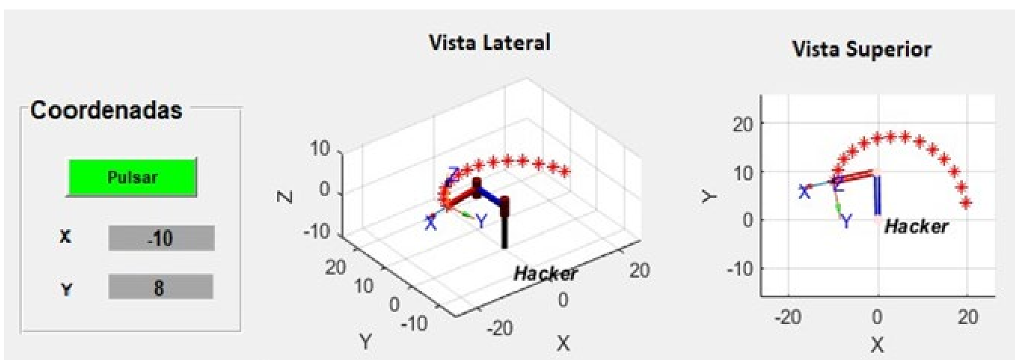


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Figure 13. Career in mode of operation Coordinates (Physical)

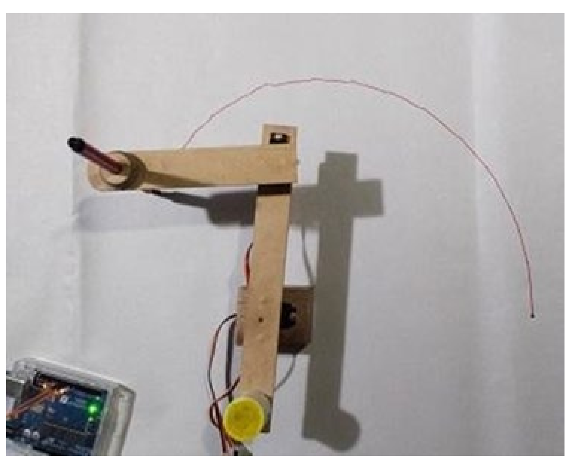

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Figure 14. Trajectory in mode of operation Area of Job (Simulation)

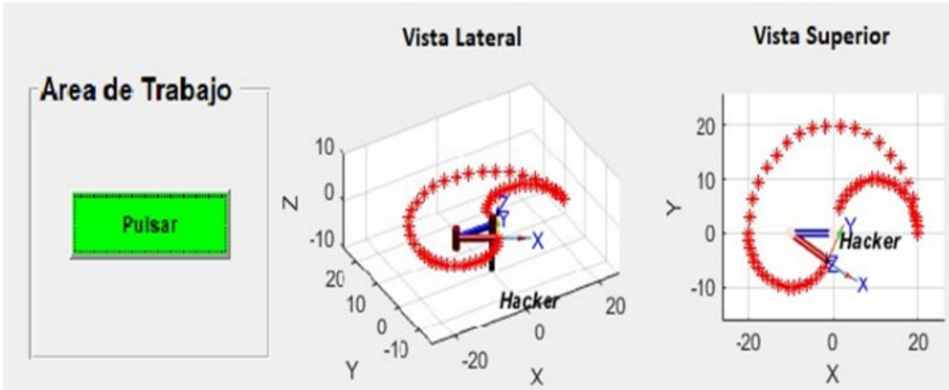

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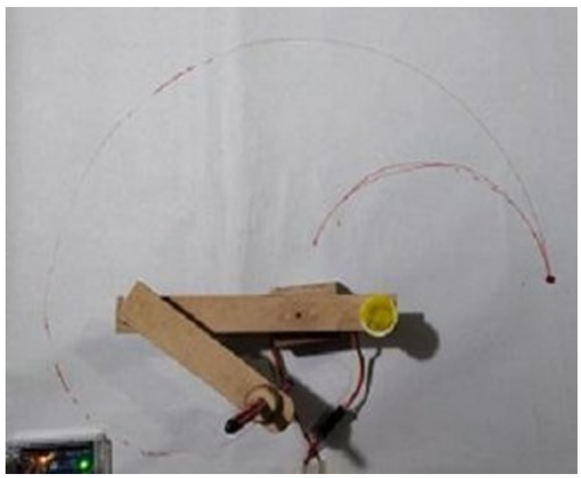
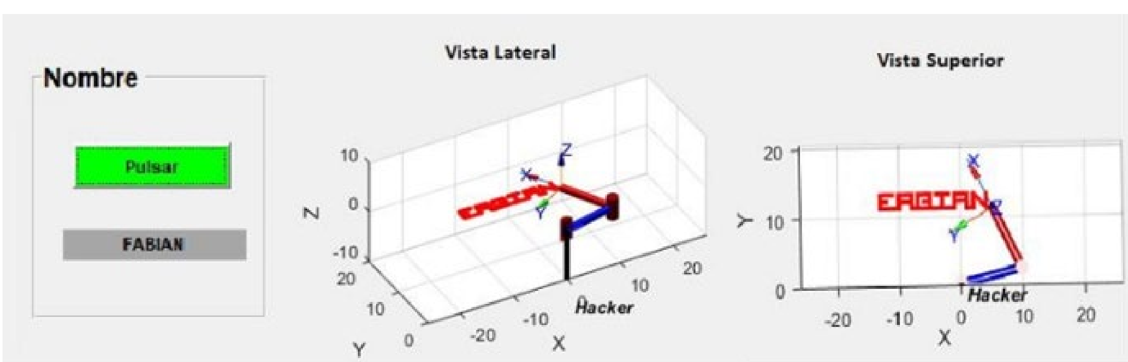
Figure 15. Trajectory in mode of operation Area of Job (Physical)



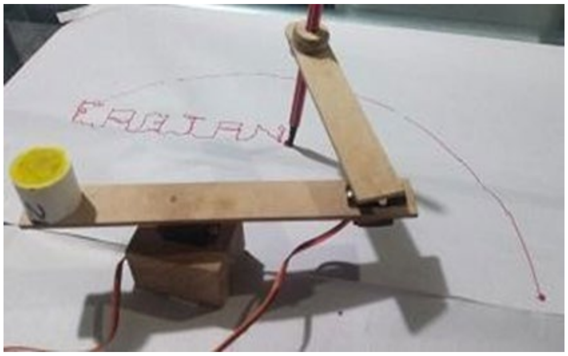
Source: Own.

Figure 16. Trajectory in mode of operation Name (Simulation)



Source: Own.

Figure 17. Trajectory in mode of operation Name (Physical)



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5. Conclusions

The 2R robot integrated by two servomotors and an Arduino Uno microcontroller, programmed through MATLAB, showed that it is a flexible and low-cost solution for applications that require graphic expression skills (e.g. writing alphabetic characters). where they verified of shape acceptable the different movements that performs the 2R robot in each of the operating modes (manual, semi-automatic and automatic), so much in simulation (Interface graph) as in the mounting physical (servomotors), demonstrating So the effectiveness of the equations raised in the kinematics direct and inverse of robot 2R, already that saying robot get arrive to the spot wanted of agreement to the mathematical modeling. However, it is important to highlight that the character strokes are not well defined in the physical assembly due mainly to the type of servomotors (MG90), which do not have a high precision in the desired angle, other aspects that affect the quality of the strokes is the structure mechanics of the robot and the processing and communication time between Matlab and Arduino, and the computational cost of Matlab is considerable, which causes a significant waiting time between the shipment of the angle to the first servo and the shipment of the angle to the second servo.

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