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Title: Development of interface for kinematic analysis of a delta-type parallel robot

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Introduction

In its original conception, a parallel robot in delta configuration consists of three kinematic chains connected to both a base and a mobile platform (Clavel, 1991). The adoption of a specific location by the mobile platform is established by combining the movement of each chain, restricting it to remain parallel to the base (Codourey, Clavel, & Burckhardt, 1992). The models for the respective forward or inverse kinematic analysis are defined, whose solution establishes the location of the end effector from the movement of each actuator or vice versa, respectively (Kuo, 2016).

From the evolution of computing, the development of software interfaces has expanded the development of algorithms, increasingly sophisticated, for the efficient and precise analysis of the capabilities of a delta robot (Rivas, Galarza, Tumbaco, Quimbita, & Galarza, 2015). Likewise, the application of analytical interfaces to manipulate physical prototypes is becoming more common and simple for the exchange of information between the computer and a peripheral device (Antal, 2018) (Huang, Weng, Wei, & Kamruzzaman, 2021).

Background

Prior to this study, a prototype of a delta-type parallel robot was enabled. Thus, the continuity in the analysis of this implement aims to the development of a graphical interface that allows its management. Such interface will have to expose with certainty the spatial location of the end effector of the analyzed robot. Therefore, in order to determine the Cartesian coordinates of the end effector of the delta robot, from the manipulation of the respective joints, or vice versa, the analysis of the respective kinematic model and the development of an algorithm that synthesizes said mathematical process are essential.

An effort to provide the user, in this case, Mechatronics Engineering students from the Technological University of North Aguascalientes, a friendly environment for handling the said robot, will be made. Being understandable the deduction of the results of the own kinematic models, through their graphical presentation, and possible the transfer of such values directly to the implement controller, for its adoption by it.

Determination of geometric parameters

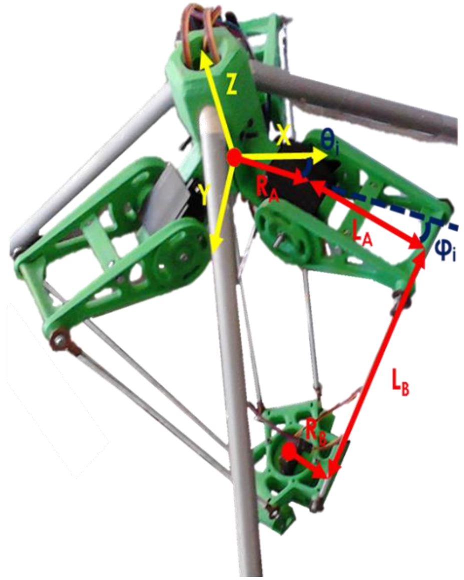


Figure 1 Reference system and geometric parameters of the parallel robot in delta configuration
Source: Own elaboration, 2021

Geometric parameter	Value
Base radius (R_A)	7.5 cm
End effector radius (R_B)	4.5 cm
Actuated link length (L_A)	9.5 cm
Driven link length (L_B)	32 cm

Table 1 Definition of geometric parameters of the delta robot used
Source: Own elaboration, 2021

Kinematics analysis of the delta robot

Fordward Kinematics

The unknowns correspond to the location of point P with coordinates (X_P, Y_P, Z_P), which is at the center of the mobile platform, once the joint angles φ_{1i}, φ_{2i}, φ_{3i} ($i = 1, 2, 3$) have been assigned, through simultaneous resolution of (1).

$$(X_i - X_P)^2 + (Y_i - Y_P)^2 + (Z_i - Z_P)^2 = L_B^2 \quad (1)$$

where:

$$X_i = (r + L_A \cos\varphi_{1i}) \cos\theta_i \quad (2)$$
$$Y_i = (r + L_A \cos\varphi_{1i}) \sin\theta_i \quad (3)$$
$$Z_i = -L_A \sin\varphi_{1i} \quad (4)$$

Inverse Kinematics

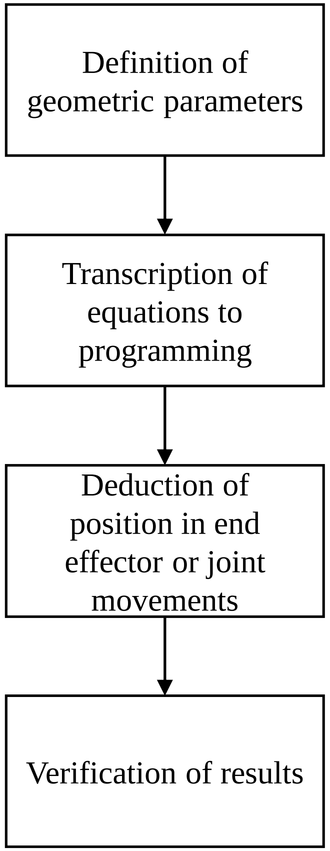
The unknowns are the joint angles φ_{1i}, φ_{2i}, φ_{3i} ($i = 1, 2, 3$) to be established, given the proposal of a particular spatial location for point P, where (5) defined for the j–th extremity of the robot can be expressed as a function of $\cos\varphi_{1i}$ and $\sin\varphi_{1i}$.

$$l_i \cos\varphi_{1i} + m_i \sin\varphi_{1i} = n_i \quad (5)$$

where:

$$l_i = 2rL_A - 2L_AX_P \cos\theta_i - 2L_AY_P \sin\theta_i \quad (6)$$
$$m_j = 2L_AZ_P \quad (7)$$
$$n_j = 2rX_P \cos\theta_j - 2rY_P \sin\theta_j + X_P^2 + Y_P^2 + Z_P^2 + r^2 + L_A^2 - L_B^2 \quad (8)$$

Algorithm & Graphical Interface



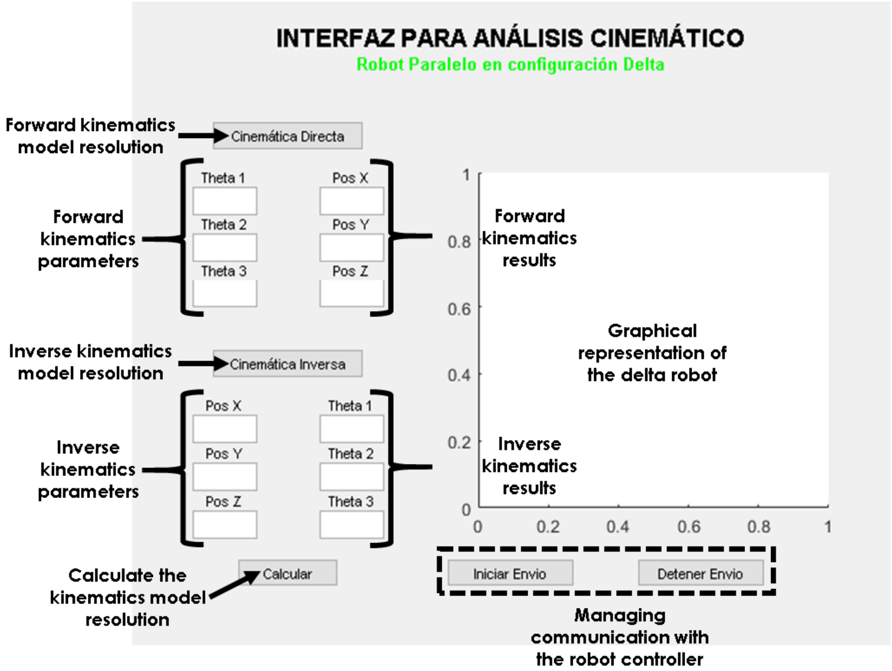
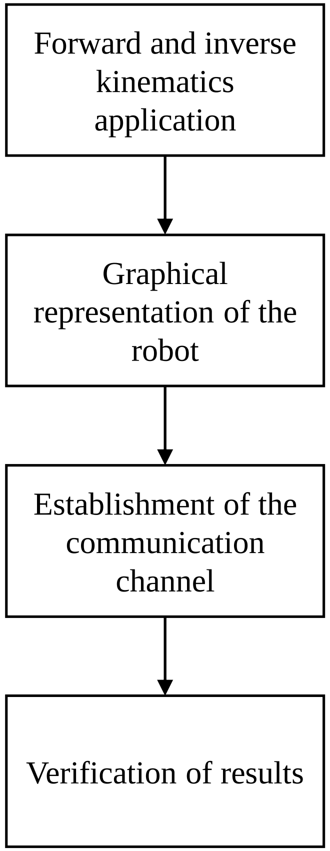


Figure 2 Graphical interface for kinematic analysis of the delta robot
Source: Own elaboration, 2021



Interface-Controller-Robot Communication

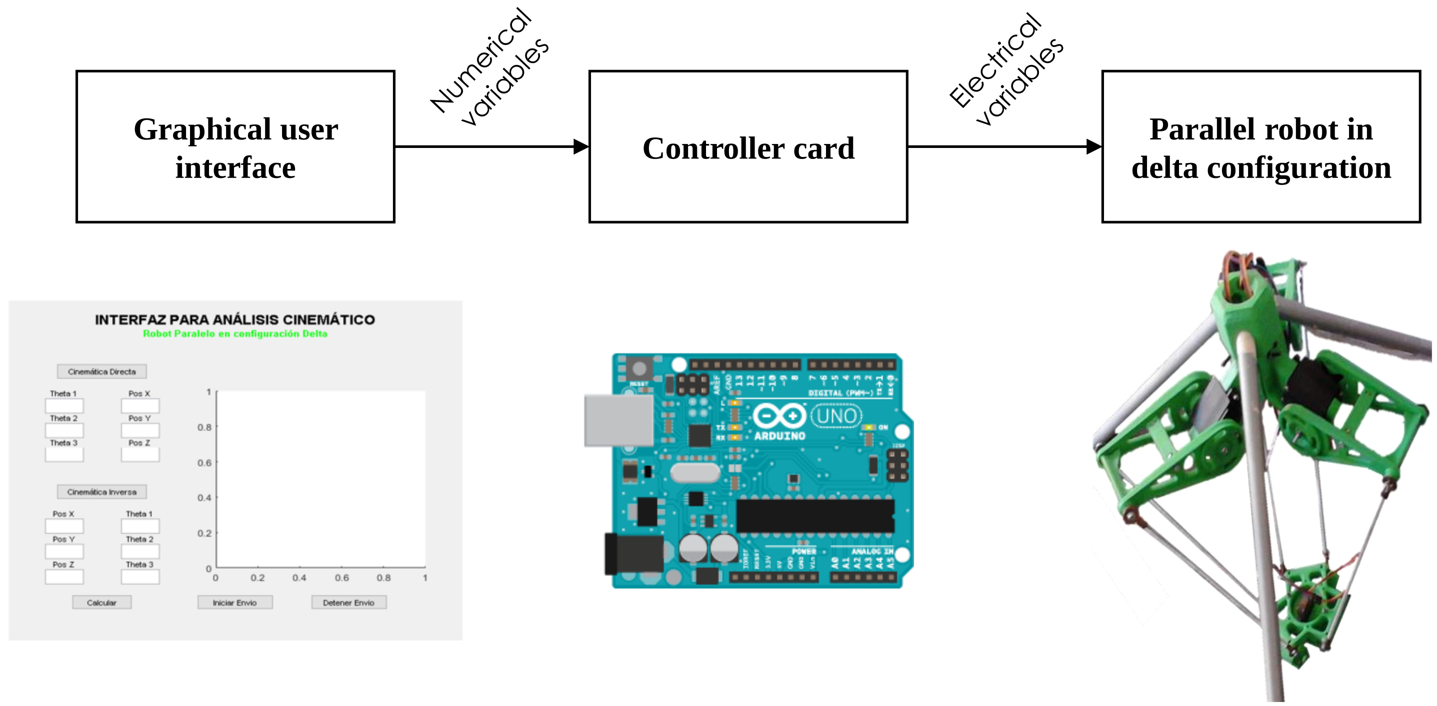
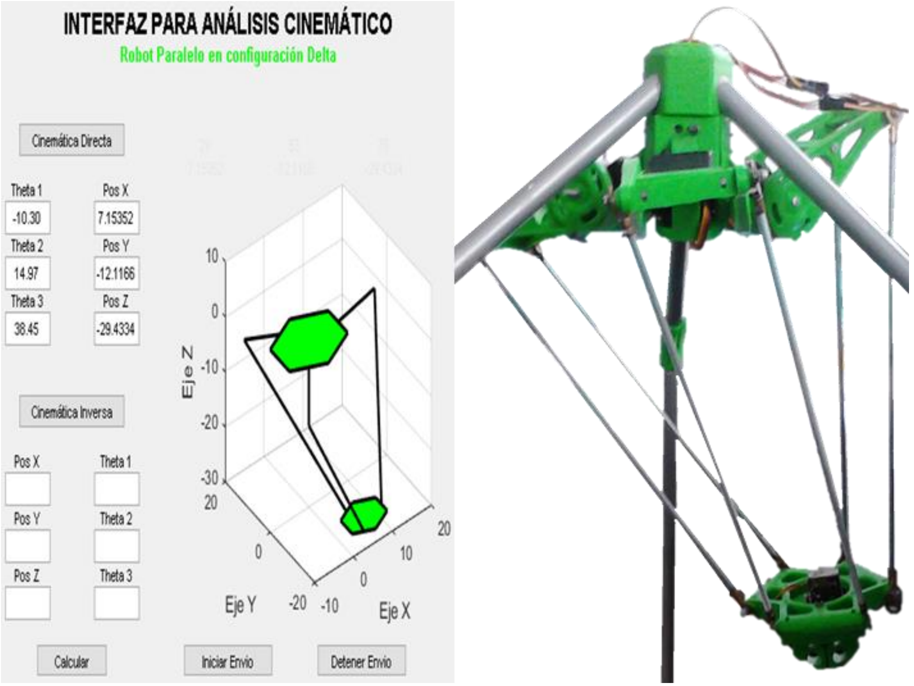


Figure 3 Interaction between graphical interface, controller card and robot

Source: Own elaboration, 2021

Operational tests (Forward Kinematics)



a) *b)*

Figure 4 Test result of forward kinematic model in: *a)* the graphical interface and *b)* the delta robot

Source: Own elaboration, 2021

Component	Desired value (cm)	Real value (cm)	Difference (cm)
X coordinate	7.154	7.010	0.143
Y coordinate	-12.117	-11.967	0.142
Z coordinate	-29.433	-29.524	0.091

Table 2 Test values of forward kinematic model, in Cartesian coordinates

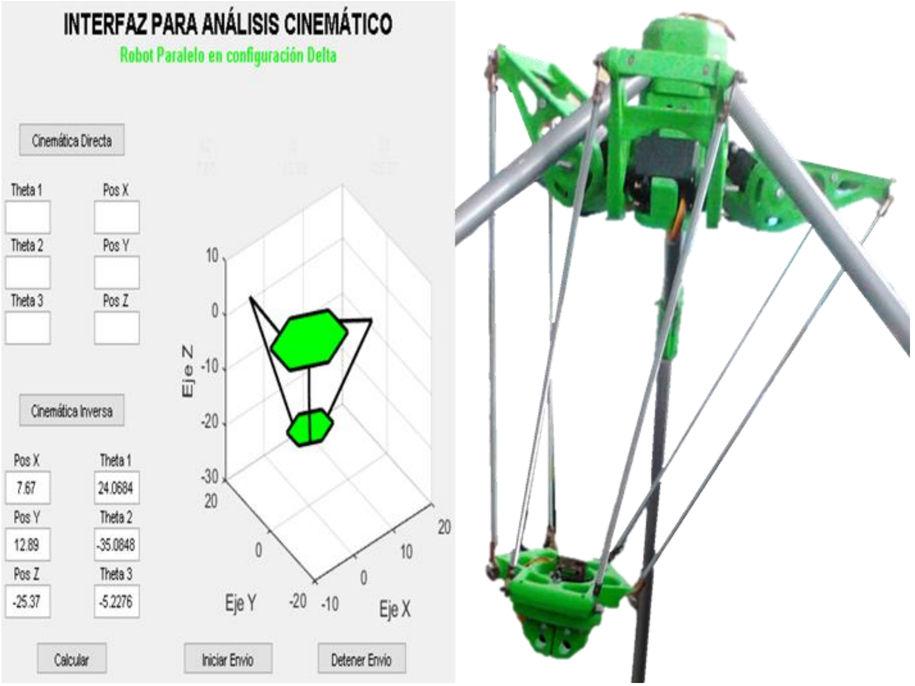
Source: Own elaboration, 2021

Component	Desired value	Real value	Difference
Magnitude r	32.624 cm	32.623 cm	0.001 cm
Angle θ	-59.442°	-59.658°	0.216°
Angle φ	154.449°	154.826°	0.377°

Table 3 Test values of forward kinematic model, in spherical coordinates

Source: Own elaboration, 2021

Operational tests (Inverse Kinematics)



a) *b)*

Figure 5 Test result of forward inverse model in: *a)* the graphical interface and *b)* the delta robot

Source: Own elaboration, 2021

Component	Desired value (cm)	Real value (cm)	Difference (cm)
X coordinate	7.670	7.709	0.039
Y coordinate	12.890	12.836	0.054
Z coordinate	-25.370	-25.397	0.027

Table 4 Test values of inverse kinematic model, in Cartesian coordinates

Source: Own elaboration, 2021

Component	Desired value	Real value	Difference
Magnitude r	29.472cm	29.482cm	0.010cm
Angle θ	59.246°	59.012°	0.234°
Angle φ	149.407°	149.478°	0.071°

Table 5 Test values of inverse kinematic model, in spherical coordinates

Source: Own elaboration, 2021

Conclusion

A particularity of parallel robots and specifically, of the delta type, is the analysis of kinematic models of greater abstraction to provide a solution to the location of their end effector, than in the case of their serial similes. Thus, from the study of the respective forward and inverse kinematic models, the programming of algorithms was developed that would concentrate and ensure the functionality of both.

On the other hand, the integration of the graphical interface for the kinematic analysis of the delta robot, allowed to provide an improved visual aspect both to the data required for the execution of a particular model, as well as to the results derived from such process. Then, such results would be sent to the robot controller itself, for the management of the associated electrical signals.

The real functionality of the implemented system was ensured through Matlab software in communication with Arduino hardware. In this way, it is possible to verify that despite being a test prototype, the implement developed, and manipulated from a computer interface, provides an adequate procedure in the scope of specific positions or joint movements requested.

References

Antal, T. A. (2018). Considerations on the serial pc-arduino uno R3 interaction, in java, using jdeveloper, for a 3r serial robot, based on the ardulink library. Acta Technica Napocensis-Series: Applied Mathematics, Mechanics and Engineering, 7-10.

Clavel, R. (1991). Conception d'un robot parallèle rapide à 4 degrés de liberté (Tesis Doctoral). Lausanne: Ecole Polytechnique Federale de Lausanne.

Codourey, A., Clavel, R., & Burckhardt, C. W. (1992). Control algorithm and controller for the direct drive delta robot. Control Robot 1991, 543-549.

Huang, X., Weng, F., Wei, Z., & Kamruzzaman, M. M. (2021). Application and research of robot sorting system based on LabVIEW. Journal of Intelligent & Fuzzy Systems, 1-8.

Kuo, Y. L. (2016). Mathematical modeling and analysis of the delta robot with flexible links. Computers & Mathematics with Applications, 1973-1989.

Laribi, M. A., Romdhane, L., & Zeghloul, S. (2007). Analysis and dimensional synthesis of the delta robot for a prescribed workspace. Mechanism and Machine Theory, 859-870.

Rivas, D. R., Galarza, E. E., Tumbaco, D. C., Quimbita, W. E., & Galarza, O. V. (2015). Delta robot controlled by robotic operating system. ITECKNE, 54-59.

Sánchez, R. E., Castillo, E., González, J. J., & Balmaceda, A. L. (2015). Análisis del desempeño cinetostático de un robot paralelo tipo delta reconfigurable. Ingeniería Investigación y Tecnología, 213-224.

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