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Original Research Article

PA10 Robot's Movement Through Natural Interface

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ABSTRACT

This paper introduces a natural interface for the movement of PA10 industrial robot and the implementation of its system. In order to evaluate the availability of these interfaces and the difference between the trajectory input by using its own development method and the trajectory executed by the robot, the mathematical model of PA10 robot is preliminarily established, and its motion is simulated in unity 3D graphics engine. Subsequently, the leap motion capture device is added as the main element of the natural interface, and tracks the movement of the user's palm during the execution of various trajectories of the simulation software and the actual robot. The results show that the tracking error between the expected trajectory and the actual trajectory of PA10 robot is very small.

Keywords: *Gesture Capture; Robot Control; Jumping Motion; Natural Interface; PA10 Robot; Trajectory Tracking*

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1. Introduction

In recent years, theft has played a representative role in the development of different fields serving mankind[1]. Considering their precision, accuracy, rapidity and consistency in different environments, they show the highest level of performance and quality in operation, and allow them to be brought to other environments to maintain their above quality[2,3]. In particular, it works in industry[4] (casting, welding, loading and unloading materials), at home[5] (cleaning, maintenance, accompanying), in the military environment[6] (detection, elimination of risk factors, transportation, loading materials on aggressive land, security and attack systems) and in medicine. There are opportunities to integrate these advantages into this environment and use them to promote medical practice[7]. Mainly, their work in this environment focuses on the assistance of surgery, diagnosis, scanning and other activities[8], which enable doctors to improve their ability to move and scan the body cavity that cannot be accessed by hands[9]. These qualities provide great advantages in many types of surgery, including laparoscopic surgery[10,11]. It is defined as the most important one in this field. It is realized through a series of small holes in the abdomen, in which the instruments required for surgery (such as endoscopy, forceps and scissors) are introduced[12].

However, in most cases, these robotic auxiliary devices require a physical feedback structure between the machine and the operator in their components, in which the tasks of displaying the working area and operating the instrument can be performed through a set of issued drive commands[13].

One of the biggest difficulties is due to the complexity of its mane-jo, which produces opposite results in the learning process and makes it scattered and slow[14], which is directly proportional to the complexity of the robot. This requires new alternatives for managing these assistants[15].

In the past few years, Cauca University and its industrial automation research group have developed a series of APLI research projects, each of which involves building coaches in a simulated virtual environment and replicating some types of surgery in the virtual environment. In order to further explore this topic, this paper shows the operation of PA10 robot, which is used in various surgical experiments and moves through natural interface. These experiments were conducted at the University of Malaga in Spain.

This article is divided into the following parts. The overall design of the system is preliminarily shown. Then, the mathematical modeling of the internal function of the free arm, the principle of gesture recognition algorithm and its integration with joint motion control are given. Finally, the test results directly carried out on PA10 robot are given.

2. Methodology

A natural interface consists of a series of elements that are allowed to be used in some applications. In this case, choose your own design and implementation for the developed application as shown below.

2.1. Overall system design

The system consists of two main units, which constitute the function of the robot (**Figure 1**). The first unit, called the hardware unit, consists of a physical structure or mechanical arm, a power supply, a control computer, a mushroom emergency device, and a motion capture device (in this case, a commercial jumping motion device). On the other hand, the second unit (software unit) is composed of control algorithm, gesture recognition algorithm and three-dimensional animation software.

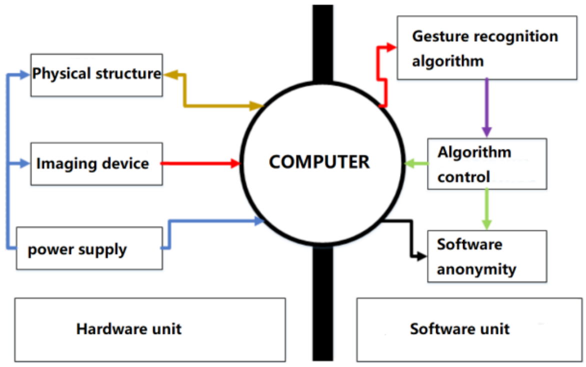

Figure 1. The overall system design.

2.2. Hardware unit

Mitsubishi PA10 industrial robot (**Figure 2**) is used for this development. It is a joint arm with seven rotating joints, each composed of its own motor.

Figure 2. Arm in industrial PA10 uses do.

On the other hand, as a gesture capture device, there is a jumping motion (**Figure 3**). This commercial device provides two encapsulated cameras used as sensors to detect and track hand and finger movements.

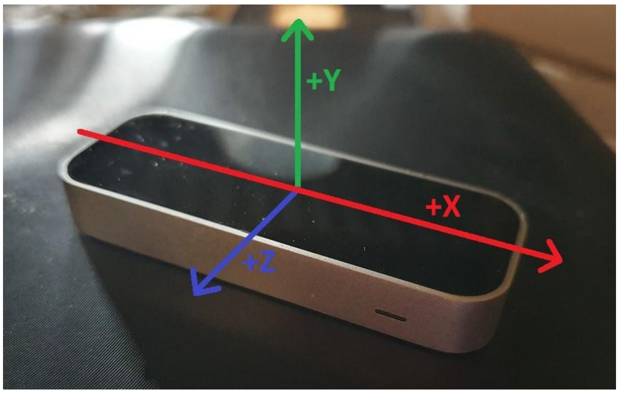

Figure 3. Motion capture device.

The described devices belonging to hardware units are interconnected and concentrated on a computer with control software.

2.3. Software unit

It consists of three basic elements, as shown below.

2.4. Gesture recognition

It's an algorithm for interpreting, detecting and recognizing gestures in three-dimensional space. In this case, during the execution of the motion or task of the control algorithm, the Cartesian position of the right palm is used as the position of the robot end effector, where the motion area is limited by the jumping motion (about 61cm^3[16]) and the workspace of the articulated arm PA10. This development is carried out under the operation of the local development library, which is developed for different ides (programming).

2.5. Control algorithm

It consists of the mathematical model of motion control and the motion control board of each joint. **Figure 4** shows a representation of the internal operation of the move to (red perimeter) algorithm. Firstly, the motion or work instructions provided by the exposed gesture recognition algorithm are input, and then the mathematical model is input, which provides a motion cup for the operation of software animated robot and actual physical structure.

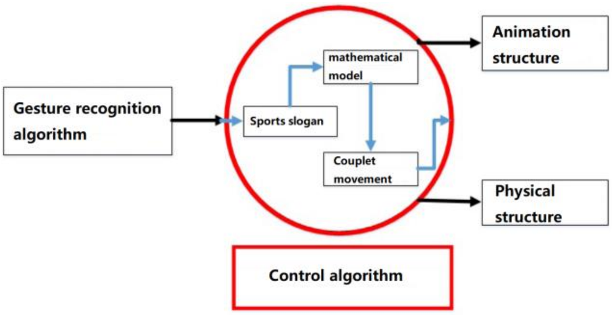

Figure 4. Working principle of algorithm control.

In both cases, since the input signal is located in the workspace of the articulated robot, there is no scaling between slogans. If unexpected movements (such as sliding, falling, etc.) occur within the sampling range of the input trajectory or outside the workspace, the control algorithm does not consider these movements and stops when its operating limit is reached. In addition, the robot system has an emergency mushroom, which will activate the brake of each motor when necessary.

The mathematical model of motion control is as follows.

2.6. Mathematical model

The structure of the seven joints or seven degrees of freedom industrial robot PA10 produced by Mitsubishi is shown in **Figure 5**.

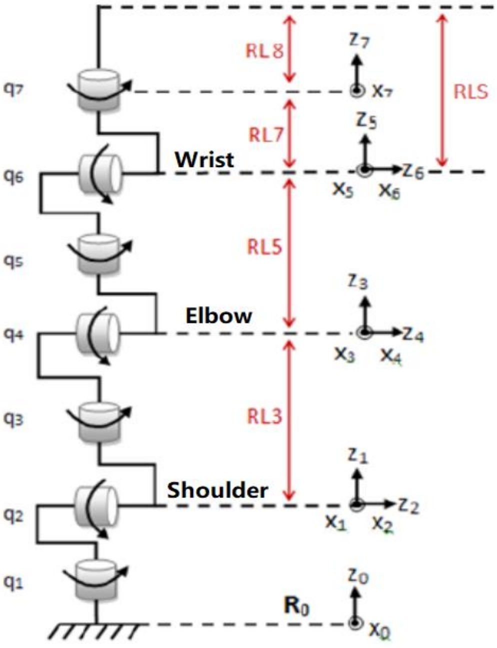

Figure 5. Diagra ma cine matica del RO BOT PA-10[12].

Through the analysis of the shafts and joints of Dombre and Khalil described[17], the geometric parameter table (**Table 1**) is obtained. It should be clarified that in the above parameter table, due to the distance RL8 shown in the above figure (**Figure 5**), the eighth joint is located between the joint axis 7 and the end of the terminal organ.

Table 1. Geometric parameter PA-10[12]

j	σj	αj	dj	Θj	rj
1	0	0	0	q1	0
2	0	–90	0	q2	0
3	0	90	0	q3	RL3
4	0	–90	0	q4	0
5	0	90	0	q5	RL5
6	0	–90	0	q6	0
7	0	90	0	q7	RL7
8	0	0	0	0	RL8

(Source: self-compiled).

Where *j* represents the number of joints analyzed, *σj* is the joint type (the value of rotating joint is 0 or the value of prism is 1), *αj* and *θj* depend on the rotation angle of joint or rotating joint, *dj* and *rj* refer to the distance between joint axes or the displacement of prism joint[18,19].

With the help of robot modeling software Symoro and robot speed table (**Table 1**), the dynamic model (MDD, MDI: direct and reverse dynamic model) and geometric model (MGD, MGI: direct and reverse geometric model) of PA-10 robot are established. The dynamic model will be used to simulate and control the robot, while the geometric model is used to verify the motion of the mechanism joints. In particular, the inverse geometric model predicts the angle at which each joint must be positioned to the desired Cartesian position. These angles are:

$$q1 = \pm arctan\left(\frac{yc}{xc}\right)$$

$$q1 = \pm arctan\left(\frac{yc}{xc}\right)\ (1.1) q2 = \pm arccos\left(\frac{zc}{RL3}\right)$$

$$q3 = \pm arctan\left(\frac{zm}{xm}\right)$$

$$q4 = \pm arccos\left(\frac{-ym - RL3}{RL5}\right)$$

q1, q2, q3, q4, q5 and q6 are joint variables of each joint of robot PA10 in response to the motion command input to system. On the other hand, the variables xc, yc, zc, xm, ym and zm represent the Cartesian positions of the elbow (joint 3) and wrist (joint 4), while the variables xd, yd and zd are coordinates corresponding to the required value or input, in this case indicated by motion.

2.7. Animation software

In the visual studio 2017 compiler, user interface applications for virtual and physical prototype operations are built in unity 3D graphics development engine using C# programming language. In order to start the work of the interface (**Figure 6**), there is a button to start and end the data acquisition of the gesture capture device, which will be reflected in the three-dimensional simulation and the actual arm. It should be clarified that the motion is carried out in both physical prototype and virtual prototype.

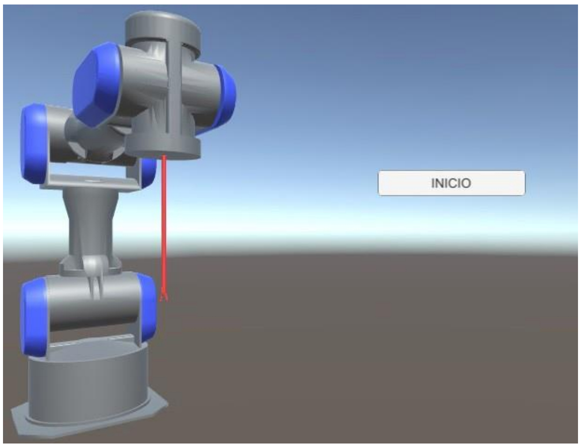

Figure 6. User interface (Source: self-compiled).

2.8. T2 system operation

First, the user places the gesture capture device on the flat plate for jumping movement, then executes the motion signal in front of the device with his right hand, and generates a working slogan, as shown in **Figure 7**.

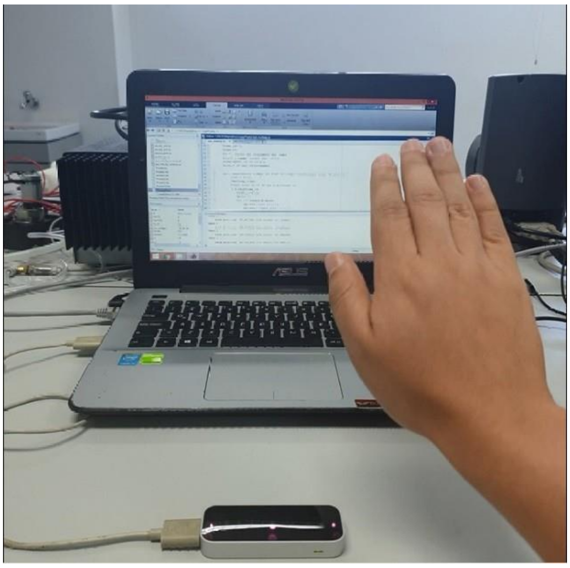

Figure 7. Initial motion capture (Source: self-compiled).

Then, this command is input into the control algorithm, which is responsible for providing cups in response to each joint motor to perform the required motion. This activity will be copied from beginning to end until the user presses the emergency mushroom button or the end button in the built user interface. The physical structure and virtual representation are initially located in the location shown in **Figure 8**.

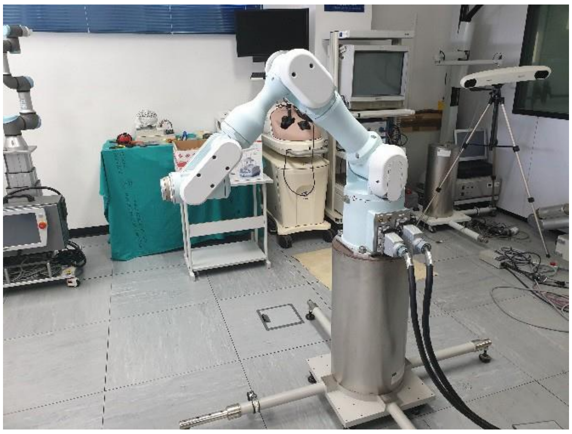

Figure 8. Initial position of robot PA10 (Source: self-compiled).

It should be clarified that in the motion of the physical structure, the motion axis changes, because as shown in **Figure 9**, the jumping motion and the axis of the physical structure are not in the same position.

In order to track the robot during trajectory execution, system has a function that records the state of each joint of the robot and its end effector, and obtains data such as direction, Cartesian position of the end effector, angular position of each joint, etc. In this case, during the execution of each execution track, each position of the arm execution is recorded in real time.

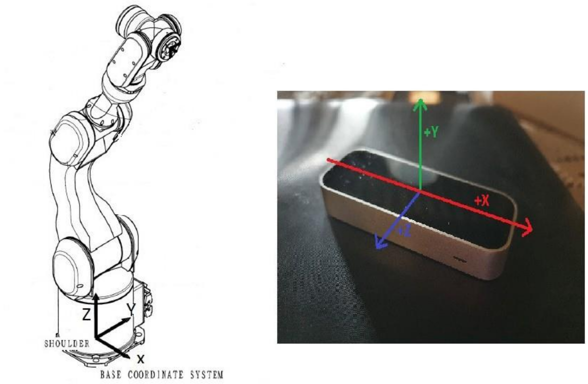

Figure 9. The Cartesian axis of jumping motion is related to the physical structure of PA10.

3. Result

In the case of executing four three-dimensional motion commands (**Figure 10–13**), the following manipulation tests are carried out on the PA10 robot. These commands will be executed by the articulated arm by tracking the trajectory input by the robot end effector.

Once the commands are input with the right hand, the trajectory of the robot arm in response to these commands can be obtained. The following figure shows the comparison of blue and red tracks.

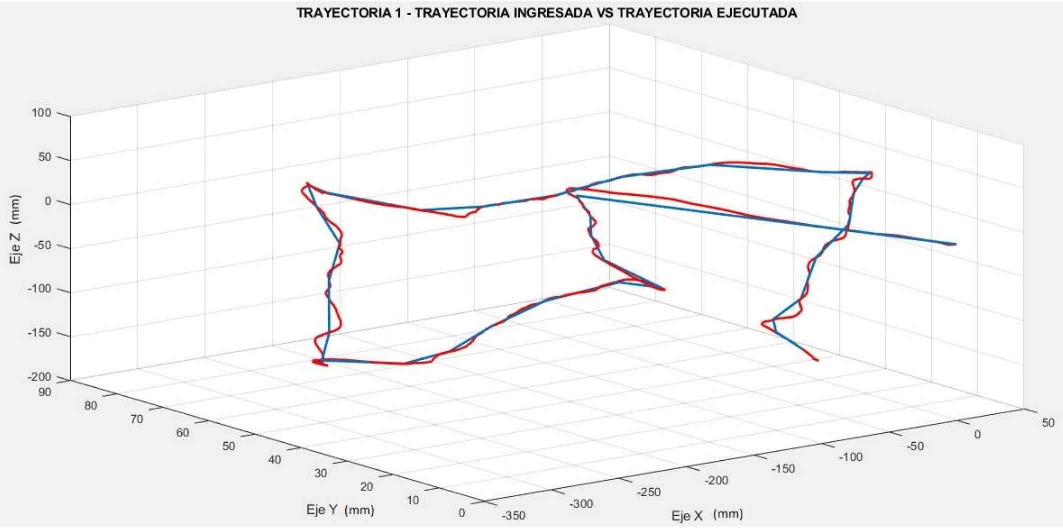

Figure 10. Path 1, the comparison between the input path and the executed path.

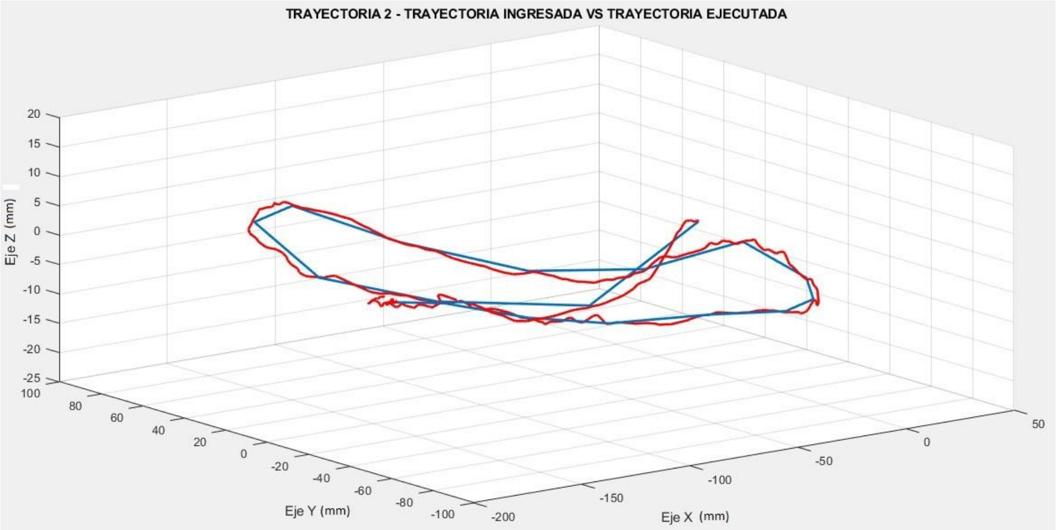

Figure 11. Path 2, the comparison between the input path and the executed path.

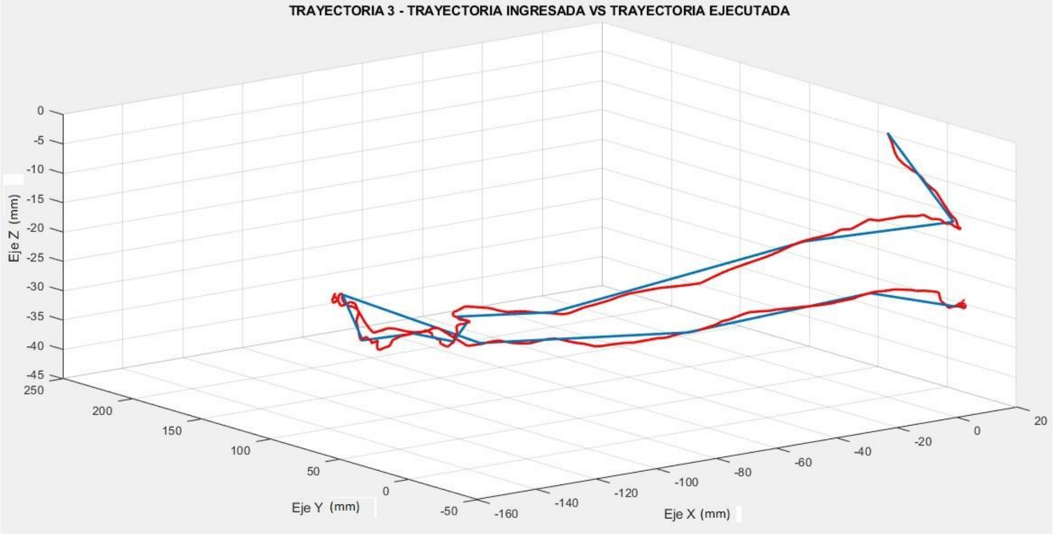

Figure 12. Track 3, the comparison between the input track and the executed track.

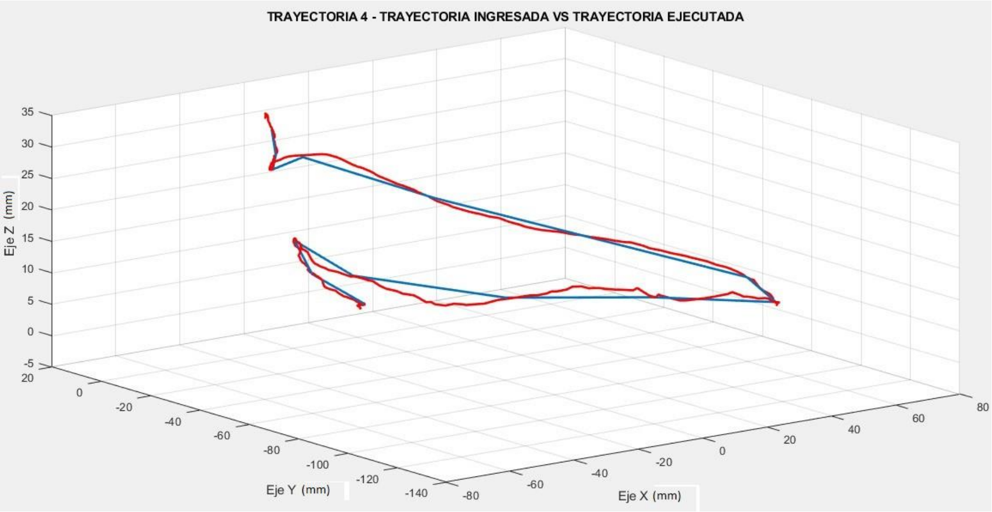

Figure 13. Path 4, compare the input path with the executed path.

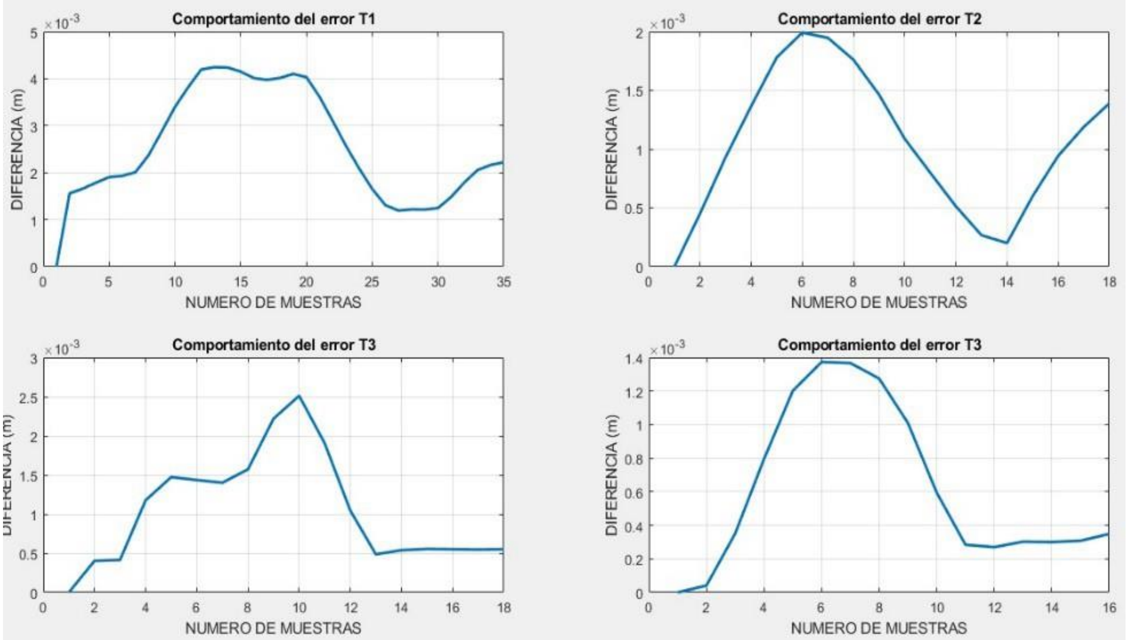

Figure 14. The behavior of the error signal of these four trajectories.

Figure 14 shows the Cartesian error for each of the four trajectories. It can be noted that, for example, when performing path 1 (**Figure 10**), the difference between the required signal and the obtained signal does not exceed 5 × 10-3m, and the average error of the four tests is 1.3 × 10-3m (slightly greater than 1mm).

In addition, in **Figure 15**, the motion sequence performed by the actual arm during the execution of track 1 is given (**Figure 10**). The results show that the error obtained is mainly due to the jump accuracy of the device. In addition, the scaling factor between the input track and the execution track is a value that directly affects the performance and calculation of the error value.

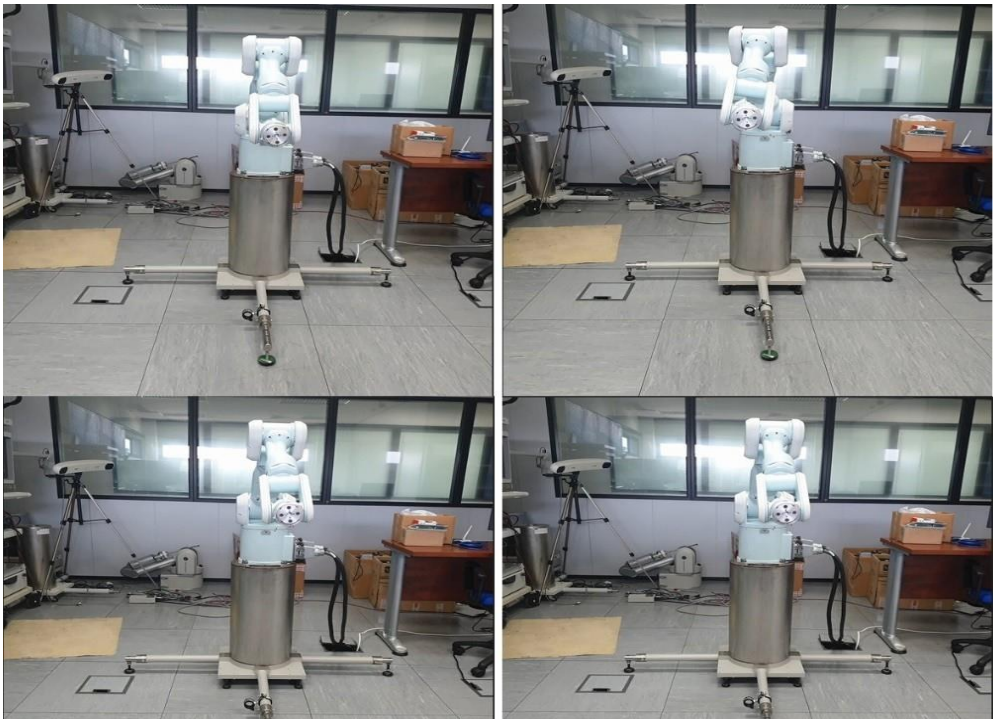

Figure 15. The motion sequence of robot PA10 is used for the initial trajectory.

4. Conclusion

This article shows a system that allows manipulation of the PA10 robot through a natural interface. The mathematical model of the 7-DOF robot is established, and its behavior is simulated by unity 3D graphics engine. As a natural interface, the leap motion device is used to read the movement of the user's hand relatively accurately.

The test shows that there is a very good consistency between the motion of the user's hand, the motion of the simulated robot and the motion of the end organ of the actual PA10 robot. The quadratic error between the required input and the obtained trajectory is less than 10%.

The future goal is to build an environment-friendly system, in which the human abdomen and its corresponding inlet holes are simulated to determine the potential of using natural interfaces at some stages of the surgical process.

Conflict of interest

The authors declare that they have no conflict of interest.

References

1. Barrientos A. Nuevas aplicaciones de la robótica: Robots de servicio [A new application of robotics: service robot] [Online]. 2002. Available from: https://www.researchgate.net/profile/Antonio_Barrietos2/publication/228889902_Nuevas_aplicaciones_de_la_robotica_Robots_de_servicio/links/0c96052855198b0438000000.pdf.
2. Sanchez Martin FM, Millán Rodriguez F, Salvador Bayarri J, et al. History of robotics: From Archytas of Tarentum until Da Vinci robot (Part I). Actas Urológicas Españolas 2007; 31(2): 185–196.
3. Flor Ángela BS, Alejandro FG. La robótica como un recurso para facilitar el aprendizaje y desarrollo de competencias generales [Robots as a resource for learning and developing general abilities]. Teoría de la Educación en la Sociedad de la Información 2012; 13(2): 120–136.
4. Arnaldo Héctor O, Fernando Javier L, Zulma C. Robótica, informática, inteligencia artificial y educación [Robotics, computer science, artificial intelligence and education] [Online]. Carreras: Computer major university network (RedUNCI); 2007. Available from: http://sedici.unlp.edu.ar/handle/10915/20504.

5. Efraín GR. Control de un robot móvil en entornos domésticos [Control of mobile robots in the home environment]. Colombia: Columbia National University; 2013.
6. Gaitan Rodríguez A. Cibernética en la guerra contemporánea: Definición de nuevos escenarios estratégicos y operacionales [Cybernetics in contemporary warfare: Definitions of new strategies and operational scenarios] Estudios en Seguridad y Defensa 2015; 10(20): 117–131.
7. D Galleano. Robótica médica [Medical robotics] [Online]. 2016. Available from: http://jeuazarru.com/wpcontent/uploads/2014/10/robotica_medicinal.pdf.
8. Vivas Alban OA. Aplicaciones de la robótica al campo de la medicina [Application of robotics in medicine]. Revista Pulsos 2007; 9: 32–38.
9. Marcos BS, Cristián MB. Medicina y robótica [Medicine and robotics] Revista Médica Clínica Las Condes 2005; 16(3): 157–167.
10. Mishra RK. Textbook of practical laparoscopic surgery. New Delhi: Jabby; 2013.
11. Escobar PF, Falcone T. Atlas of single port, laparoscopic and robotic surgery. New York: Springer; 2014.
12. Fernández-Riomalo CE, Guástar-Morillo HA, Vivas-Albán OA. Design and modeling of a virtual PA-10 robot for surgical applications. Revista Facultad de Ingeniería 2016; 25(42): 21–32.
13. Ballantyne GH. Robotic surgery, telerobotic surgery, telepresence, and telementoring. Surgical Endoscopy and Other Intervention Techniques 2002; 16(10): 1389–1402.
14. Juanes JA, Gómez JJ, Peguero PD. 2015. Practical applications of movement control technology in the acquisition of clinical skills [Online]. Available from:https://dl.acm.org/doi/abs/10.1145/2808580.2808583.
15. Lee JY, P. Mucksavage P, Sundaram CP, et al. Best practices for robotic surgery training and credentialing. The Journal of Urology 2011; 185(4): 1191–1197.
16. Elena VM. Diseño de un algoritmo de seguimiento del instrumental quirúrgico mediante un dispositivo Leap Motion y su validación en un simulador físico [Design of surgical instrument tracking algorithm using jumping motion device and verification in physical simulator]. Madrid: Universidad Politécnica de Madrid; 2017.
17. Dombre E, Khalil W. Modeling, performance analysis and control of robot manipulators. London: Willie; 2007.
18. Fernández-Riomalo CE, Guástar-Morillo HA. Design and modeling of a virtual PA-10 robot for surgical applications. Popayan: Universidad del Cauca; 2014.
19. Vivas-Alban OA. Diseño y control de robots industriales: teoría y práctica [Design and control of industrial robots: Theory and practice]. Buenos Aires: Elaeph; 2010.