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Manipulación remota de brazo robot: Avanzando hacia la Industria 4.0

Robot arm remote manipulation: Advancing towards Industry 4.0

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Abstract

The objective is to develop a system that allows the manipulation of a robot arm through a graphical interface in Python and Arduino, with the ability to be controlled from anywhere in the world. In addition, the interface will contain a login function to access the system and two cameras will be integrated to provide a view from two different perspectives, all being seen in real time.

Resumen

El proyecto tiene como objetivo desarrollar un sistema que permita la manipulación de un brazo robot a través de una interfaz gráfica en Python y Arduino, con la capacidad de ser controlado desde cualquier parte del mundo. Además, la interfaz contendrá una función de inicio de sesión para acceder al sistema y se integrarán dos cámaras para proporcionar una visualización desde dos perspectivas diferentes, todo esto siendo visto en tiempo real.

Keywords and phrases: Industria 4.0, Brazo Robot, Reingeniería.
2020 Mathematics Subject Classification: 68N01

1 Introduction

In the era of Industry 4.0, global connectivity and digitization are completely transforming industrial processes. One of the most significant advancements in this revolution is the implementation of highly sophisticated and adaptable robotic arms capable of performing complex tasks and precise manipulations. These robotic arms have become an efficient solution for automating a wide range of industrial applications.

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An industrial robot is a manipulator with 3 or more axes, automatic control, reprogrammability, and, depending on the application, mobility. It is intended for use in industrial automation applications. It includes the manipulator and the control system [1]. A manipulator arm or robotic arm can be defined as the set of electromechanical elements that enable the movement of an end-effector (gripper or tool) [2,3].

As the industry becomes increasingly globalized, the need for more flexibility and mobility in robotic systems arises. The ability to manipulate a robot arm from anywhere in the world has become a key challenge for companies seeking to enhance their production and stay competitive.

In this context, the reengineering of a robot arm emerges as a promising solution. By adapting and enhancing an existing robotic arm, a highly efficient and connected system can be achieved, capable of operating anywhere in the world. This reengineering involves the integration of advanced technologies such as artificial intelligence, machine learning, and cloud connectivity.

Currently, many companies have not yet made the leap towards new technologies, making it essential for them to still have operators on the plant floor to operate robot arms. This is because the control panel is fixed on an industrial board.

The primary objective of this reengineering is to enable remote manipulation of the robot arm, involving control and supervision through a global network. This opens up a realm of possibilities, as operators can control and program the robot arm from any location, promoting remote collaboration, resource optimization, and real-time problem resolution.

Furthermore, the reengineering of a robot arm for Industry 4.0 goes beyond just its capability for remote manipulation; it also involves the collection and real-time analysis of data. This enables data-driven decision-making and the continuous optimization of the robot arm's performance. Integrated sensors and feedback systems provide valuable information about the working environment, allowing for the efficient adaptation and improvement of robot arm operations.

Robotic devices have been crucial in performing repetitive and demanding tasks that were traditionally carried out by human workers. In the execution of these tasks, manipulators need to be controlled to ensure that their movements in the environment enable the end effector of the manipulator to reach a specific goal, while avoiding obstacles that may appear in its path [4].

Based on the information provided earlier, the designed system relies on a graphical interface in Python that will allow users to intuitively control the robot arm. To access the interface, users will need to log in using a username and password, ensuring security and access control to the system. Once logged in, users can manipulate the robot arm using controls provided by the graphical interface. These controls will send commands to the Arduino microcontroller, which will be responsible for executing the corresponding movements in the robot arm. In addition to robot arm manipulation, the system will feature two integrated cameras.

These cameras will provide real-time visualization from two different perspectives. Users will be able to switch between the cameras to obtain different views of the environment and the objects the robot arm interacts with. To achieve remote manipulation of the robot arm, the system will connect via the Internet. This will allow users to access and control the robot arm from any location with an internet connection, as depicted in Figure 1.

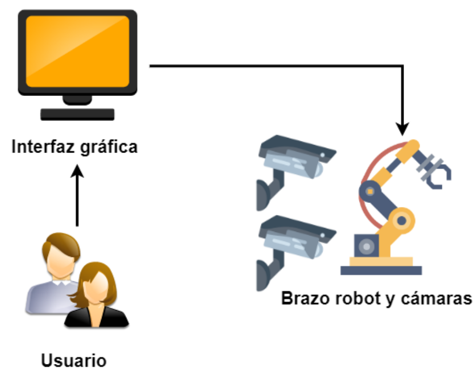

Figure 1. Development of communication between the user and the robot arm.

In this way, the mentioned need in paragraph 2 of this introduction can be addressed. It is important to mention that in this work, the robot arm will be presented to visualize its design. Additionally, the graphical interface that users or operators can use for real-time manipulation will be showcased. Lastly, but not least, the connection diagram between Arduino microcontrollers, motors, and servo motors will be displayed. The results will serve as evidence of the functionality of remote operation carried out in different parts of the world.

2 Theoretical Framework and State of the Art

As Pascual Griñán mentions [5], for centuries, humanity has shown an interest in creating beings similar to them that can carry out difficult, monotonous, or dangerous tasks on their behalf. Although the terms "robotics" or "robot" were not known back then, they were later adopted to describe this field of study. From a scientific perspective, robotics is defined as a branch of engineering that combines various disciplines, such as mechanics and electronics, among others, to design, build, and control robots. The fundamental purpose of the project was to create a scale replica of a robotic arm capable of imitating and manipulating, as described by Jesús García Caicedo [6]. Both in the industrial and educational realms, fundamental insights into the functioning of controllers, programming, and machinery used in the industry have been provided. His project was based on a model of a robotic arm controlled with an Arduino board and four servo motors, designed and built with three degrees of freedom.

According to Juan Sebastián Rojas [7], technological advances have had a significant impact on various aspects of human life, facilitating the execution of challenging tasks that previously posed various difficulties. Among the highlighted challenges are risks to physical safety, long working hours, repetitive tasks, and exposure to hazardous pollutants, among others.

As mentioned by César Reyes [8], a redesign of the robot arm was carried out with the aim of improving its weight and using more efficient materials. During the redesign process, modifications were made to the structure and components of the robot arm to reduce its total weight. This project was conducted using the same prototype of the robot arm mentioned in this article.

3 Methodology

The adoption of the Scrum methodology was proposed to achieve results within an efficient time frame, maximizing the use of resources and information. Scrum involves the continuous implementation of a set of effective practices to encourage team collaboration and achieve the best possible outcome in a project. Under this methodology, schedules are established in which progress is delivered periodically, and feedback is received from the project owner, as depicted in Figure 2.

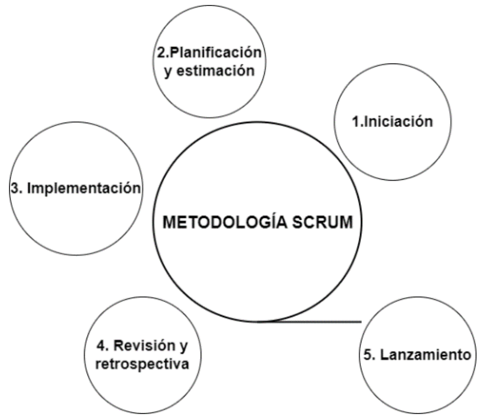

Figure 2. Scrum Methodology Diagram.

4 Reengineering of Robot Arm

The robot arm underwent a significant reengineering process to upgrade its outdated components and enhance its performance. Several key improvements were implemented, including the integration of two Arduino boards and two H-bridges (L298N) for more precise and efficient control. Additionally, a complete redesign of the robot arm was carried out, incorporating strategic perforations to reduce its weight, making it lighter for easier manipulation and mobility. The color was also changed to give it a more modern and updated appearance.

One essential aspect of the reengineering was the replacement of the old servo motors with new models. The previous servo motors were no longer functional and did not meet the desired performance requirements. Therefore, new servo motors were installed, providing increased power, precision, and durability. A new type of computer connection was also implemented to enhance communication and data transfer between the robot arm and the control system. This new connection ensures greater stability and speed in command transmission and feedback.

In summary, the reengineering of the robot arm brought significant improvements, including component updates with the incorporation of two Arduino boards and two H-bridges (L298N), a new design with perforations to reduce weight, a color change, installation of new servo motors, and an enhanced computer connection. These improvements have boosted the performance, efficiency, and functionality of the robot arm. As depicted in Figure 3, there is a before-and-after representation of the enhancements made.

Figure 3. Before and After Reengineering.

5 Design and Construction

A design was created using Fritzing software, as depicted in Figure 4, to establish the connection of an L298N controller with three direct current (DC) motors through an Arduino. Additionally, three servo motors were connected to another Arduino. To ensure an adequate power supply, a power source capable of voltage leveling was used. The design in Fritzing software allowed for effective visualization and planning of the component configuration.

The L298N controller was connected to the Arduino. On the other hand, the three servo motors were connected to the second Arduino, providing movement capability and precision in the required positions. It's important to clarify that due to the motors and servo motors operating at different voltages, the decision was made to include a second Arduino for proper voltage management. As mentioned earlier, one Arduino handles the motors, while the other manages the servo motors.

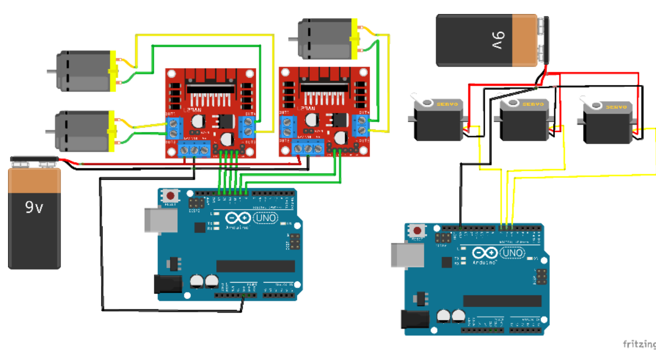

Figure 4. Design created in Fritzing showing the internal connections of the robot arm.

The assembled final product, as shown in Figure 5, demonstrates a correct integration of components, allowing complete and precise control of the robotic arm. The Arduinos, H-bridges, and motors are operating in a coordinated manner, enabling smooth and controlled movement of the arm in response to provided instructions.

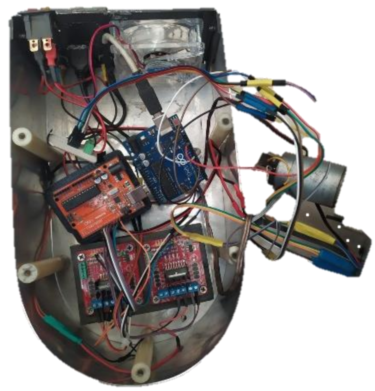

Figure 5. Photo of Assembled Components:

To ensure a stable and secure power supply, a power source was employed that allows for voltage leveling necessary for the proper operation of the components. This ensures optimal performance and prevents damage from fluctuations in electrical current.

6 Graphical interface

The project features a graphical interface developed in Python that enables the manipulation of the robot arm. Upon starting the program, a login window requiring authentication is displayed, as shown in Figure 6. Once successfully logged in, a menu with options to control the movements of the robot arm is accessed. The graphical interface provides an intuitive and user-friendly experience for interacting with the robot arm. In addition to the arm's movement manipulation options, two buttons are included to open the cameras and view them remotely. This allows the user to obtain a real-time perspective from two different points of view, which is useful for monitoring and controlling the environment in which the robot arm operates, as verified in Figure 7.

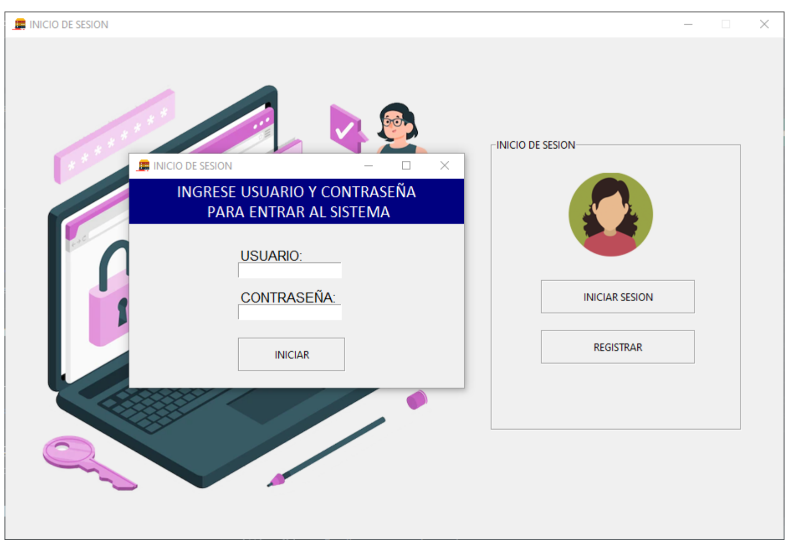

Figure 6. Preview of the Graphical Interface Login.

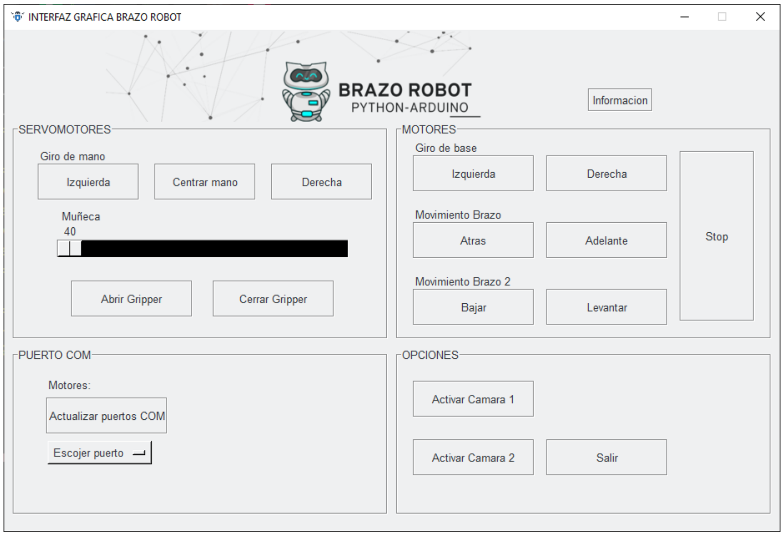

Figure 7. Preview of the Graphical Interface Main Menu.

7 Viewing Cameras

In the project, HikVision IP cameras, specifically of the Dome type, were incorporated (as visualized in Figure 8) to monitor the robot arm. These cameras are mounted on a fixed base. Additionally, a Python code was developed to open the cameras from the main menu of the interface. The inclusion of cameras in the project provides the capability to visualize the robot arm and its surroundings from different perspectives. This is useful for monitoring and controlling tasks performed by the robot arm, detecting potential obstacles, or improving the precision of movements. The Python code allows access and control of the cameras from the main menu of the graphical interface. This offers a convenient way to open and view real-time camera images without the need for external applications.

Figure 8. Preview of IP Cameras focusing on the robot arm.

8 Remote Manipulation

The capability to manipulate the robot arm remotely was implemented using the software AnyDesk. AnyDesk is a secure remote access tool that allows the control of a device from another located anywhere in the world, and the link is available [here](https://anydesk.com/es). To use AnyDesk in manipulating the robot arm, it's necessary to install the software on both the computer or mobile application, either on Android or iPhone, from which you want to control the arm and the computer connected to the robot arm. Once installed, a remote connection is established between both devices through a unique identification code.

Once the connection with AnyDesk is established, you can access the control environment of the robot arm from the remote computer. Through the intuitive graphical interface, the user can perform various actions and movements with the robot arm, such as manipulating objects, adjusting the arm's position, or executing programmed movements. As shown in Figure 9, there is a connection between both devices for manipulation. It's worth noting that it is not necessary for a person to be present at the computer to log in to AnyDesk, as a small configuration can be set at Windows startup to open the software automatically when the computer is turned on. Once the user remotely logs in, they can access the graphical interface shown in the previous section.

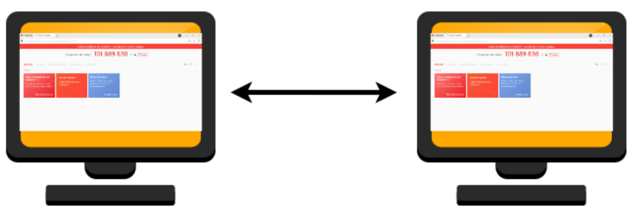

Figure 9. AnyDesk Establishing Connection Between Devices.

9 Results

In certain instances, it has been observed that one of the three servo motors of the robot arm experiences failures or requires a double click to function correctly. This issue is derived from the type of voltage used in the system. The servo motors require a 5V power supply, but as three servo motors are in operation, they demand slightly more voltage. When providing a slightly higher voltage to meet the requirements of the three servo motors, it has been noticed that the affected servo may experience problems or malfunctions in its operation. This suggests that excess voltage might be causing interference or overloading in the motor, affecting its performance.

Tests were conducted with three individuals located in different geographical regions: Colombia, Texas, and Brazil. All three individuals had a good internet connection provided by their respective service providers. During the tests, a successful connection was established with the robot arm, and it was observed that response times were quick and efficient. Additionally, visualization times using the cameras on the robot arm were evaluated. The images were found to be sharp and clear, allowing for precise visualization of the environment. This is crucial to ensure accurate and safe manipulation of the robot arm, as users can have a clear visual representation of the arm's actions. As shown in Figures 10, 11, and 12, a ping test was conducted among the three users manipulating the robot arm remotely.

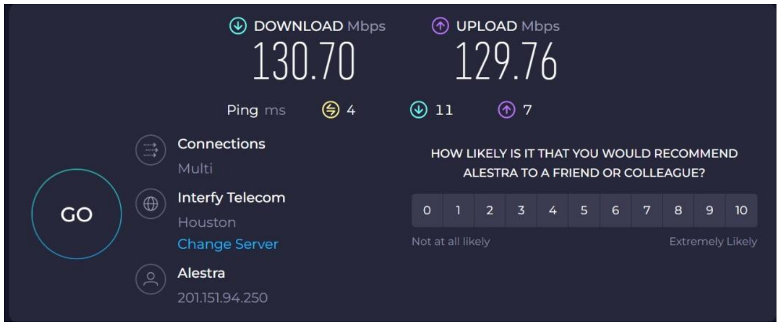

Figure 10. Ping Test in Houston, Texas.

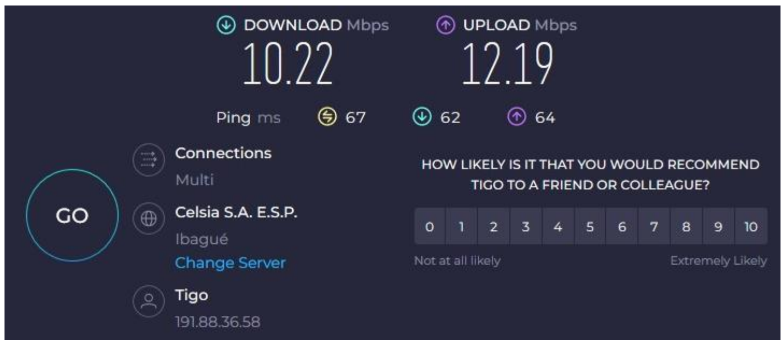

Figure 11. Ping Test in Caldas, Colombia.

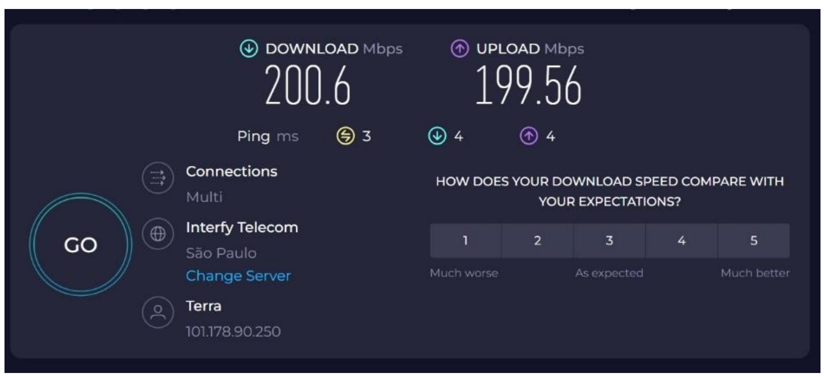

Figure 12. Ping Test in Brazil.

A successful manipulation test of the robot arm was carried out over a distance of 1547 km, as shown in Figure 13, from Texas, Houston, to Estado de México, México. During the test, the person located in Texas was able to manipulate the robot arm and visualize in real-time through the two installed cameras. The remote connection was established seamlessly, thanks to the adequate internet speed provided by the providers at both locations. This allowed the person in Texas to experience fast response times, facilitating precise and smooth manipulation of the robot arm.

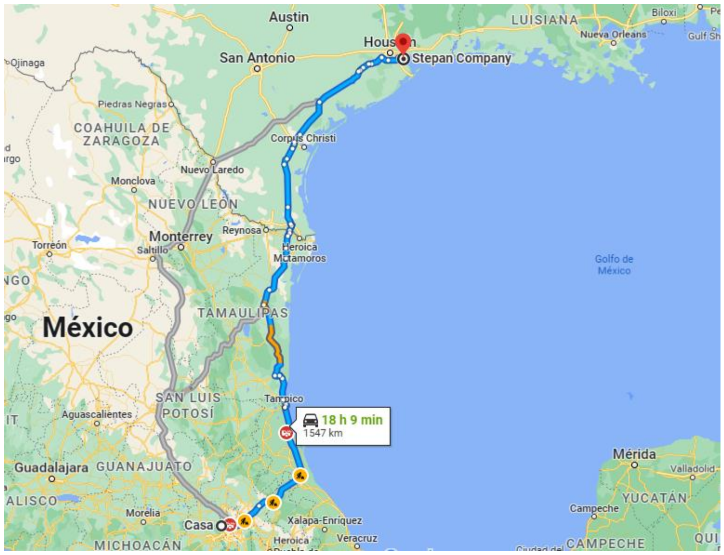

Figure 13. Geographical Locations from Texas to Mexico (Generated with Google Maps).

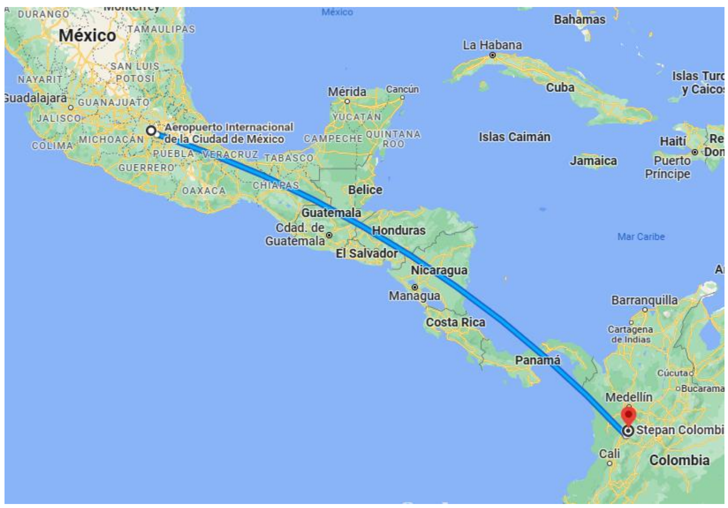

Figure 14. Geographical Locations from Colombia to México (Generated with Google Maps).

On the other hand, a manipulation test was also conducted from Colombia to state of Mexico, Mexico, as seen in Figure 14. During the test, it was achieved that a person located in Colombia could manipulate the robot arm and visualize in real-time through the two installed cameras. Despite the geographical distance, a remote connection was established that allowed the manipulation of the robot arm without major difficulties. However, due to the average internet speed provided by the providers in both locations, response times were somewhat slower than a higher-speed connection.

In the last conducted test, as shown in Figure 15, a successful manipulation test of the robot arm from Brazil to Mexico was carried out. During the test, a person located in Brazil could manipulate and visualize in real-time the images from the two cameras of the robot arm, establishing a reliable remote connection. One of the highlights of the testing was the highly satisfactory response time, which was attributed to the quality and speed of the internet connection used by the person in Brazil. This quick response allowed for smooth and precise manipulation of the robot arm, providing a favorable experience.

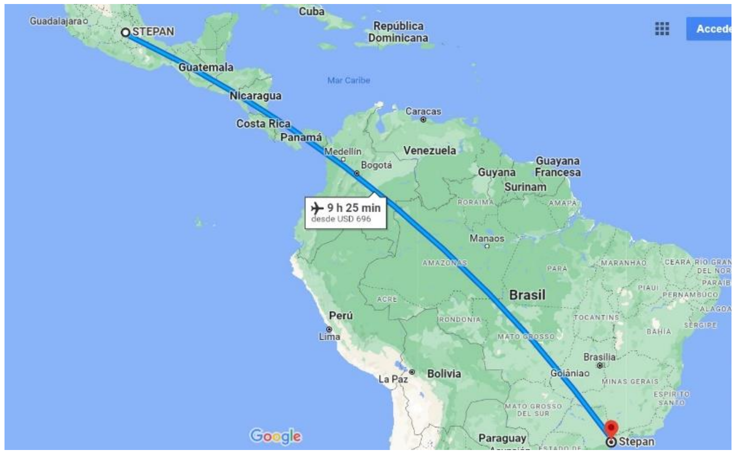

Figure 15. Geographical Location from Brazil to Mexico (Generated with Google Maps).

10 Conclusions and future work

In conclusion, the robot arm project has been a success, despite the challenges encountered during its development. Although there were some problems, such as occasional servo motor failures and the need to adjust the voltage supply, they were overcome and satisfactory operation. One of the outstanding achievements of the project is the ability to manipulate the robot arm remotely from different locations. The remote connection using software such as AnyDesk allowed for smooth and efficient communication between the user and the robot arm. Response times were fast and viewing through the IP cameras provided crisp and clear images. Despite the challenges encountered, the robot arm has proven its ability to adapt and constantly improve. The re-engineering design, the integration of new components and the implementation of a graphical interface in Python have contributed to optimizing its operation and making it easier to use.

As for the future of the robot arm, the exciting possibility of implementing manipulation through a skeletal glove is being considered. The main idea is to develop a system in which the movements of the user's hand and fingers are translated into corresponding movements of the robot arm. The goal of this proposal is to achieve a more intuitive and natural interaction between the user and the robot arm. By using a skeletal glove, the movements and gestures of the hand would be captured in real-time, and this data would be transmitted to the robot arm for synchronized movement. To achieve this, a combination of technologies would be required, such as motion sensors, real-time data capture and processing, mapping and control algorithms, and proper integration with the existing software of the robot arm.

Gratitudes

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