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Abstract -- With the evolution of science and the constant improvement of technology, robotics has become a multidisciplinary science. With the advances in computer science, mechanics, electronics, artificial intelligence and other sciences, the current robots emerge, qualified as intelligent, with improved sensory extensions with respect to their predecessors. Advances in science allow robotics to have good prospects, while increasing the complexity of it. In this project we propose the development of a hexapod robot prototype, manufactured through CAD design and printed on 3D printers, the motion control is done through the ESP32 purpose board, programmed in C language, by the Arduino IDE (free distribution). The purpose is to have a self-made didactic equipment for the implementation of different control systems, which is the reason why we start by making the prototype, its kinematic analysis and the application of a first work algorithm communicated through an APK application developed for its movements.

Keywords: Robotics, Hexapod, Denavith Hartemberg.

Abstract -- With the evolution of science and the constant improvement of technology, robotics has become a multidisciplinary science. With advances in computing, mechanics, electronics, artificial intelligence and other sciences, current robots emerge, described as intelligent, with improved sensory extensions compared to their predecessors. Advances in science allow robotics to have good prospects, but at the same time increase its complexity. This project proposes the development of a hexapod-type robot prototype, which is manufactured through CAD design and printed on 3D printers, the movement control is carried out through the ESP32 purpose board, programmed in C language, by the Arduino IDE which is free to distribute. The purpose is to have a self-made teaching equipment for the implementation of different control systems, which is why the prototype is first made, its kinematic analysis and the implementation of a first work algorithm communicated through an APK application developed for their movements.

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INTRODUCTION

Hexapod robots have been created by mimicking the physical structure of insects and arthropods, they are composed of 6 legs, which have 3 degrees of freedom (GDL), allowing mobility in terrain that other robots are not able to reach. Possible applications include the exploration of uneven terrain capable of being analyzed.

By utilizing a leg with 3 GDLs per hexapod limb, it allows for the creation of movements of greater complexity in an omnidirectional manner. (Nazar Plata, 2023) Thus walking robots have the potential to traverse rough terrain that is impassable to standard wheeled vehicles.

It is with this in mind that roboticists are developing walking robots. Sophisticated walkers mimic insects, crabs, and sometimes humans. Using a six-legged model it is possible to demonstrate the famous tripod gait used by most legged creatures (Lovine, 2002).

DEVELOPMENT

To recognize the activity of the legs or limbs of an insect we use the definition of terms according to the movement to be performed by its limb these are: protraction, promotion, retraction, adduction, abduction, elevation, depression, extension and flexion; all this is done through the mechanisms of its limb (legs) with the use of a leg of 3 degrees of freedom (GDL), figure 1. The design of a hexapod robot helps facing the obstacles that are in the path of displacement, being able to perform an adequate, fast and as far as possible, without suffering any mishap.

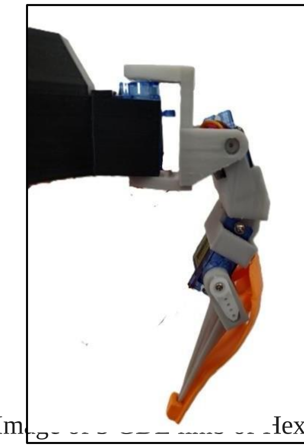

Figure 1. Image of 3 GDL limb of Hexapod Robot.

The locomotion system used in the robot prototype consists of the synchronous and coordinated movement of 6 legs, each with 3 degrees of freedom, totaling 18 servos. One of the main characteristics is to coordinate the sequence of the steps, this was solved by means of a dedicated electronic system of distributed architecture such as a multiplexer (controlled by Bluetooth communication).

For the analysis of a leg, we proceeded to name each of the assembled sections, resembling the legs of a spider, compensating the angle that the extremities of these characteristic animals have, as shown in Figure 2. Also, the angles Ø1, Ø2, Ø3 were considered for the kinematics analysis.

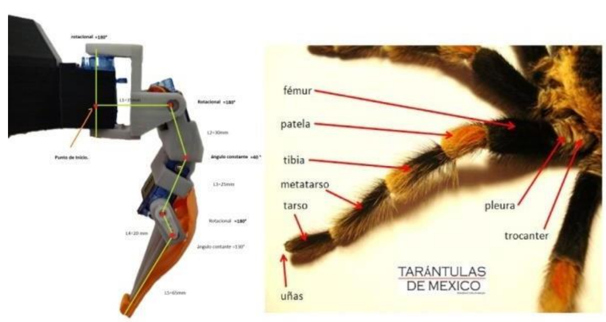

Figure 2. similarity of leg where femur, patella (considers the angle in physical), tibia are considered.

For the study of mobility of the limb it is necessary to develop the direct kinematics, this from the measurements of each section, also, propose the range of angles properly pointing out the one formed between the patella and tibia, values that are used to identify the different movements, this was determined from a lateral view (Figure 3).

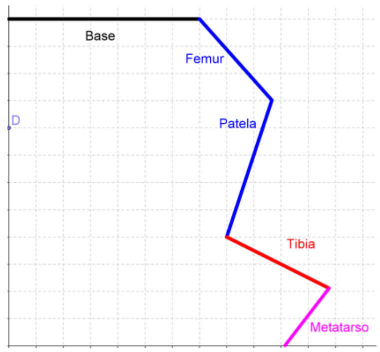

Figure 3. side view of the hexapod robot leg configuration.

The assembly of the hexapod prototype was carried out with SG90 servomotors (Figure 4), these normally have three wires (unlike DC motors that have only two); one to receive electrical power (normally in red), another for connecta ground (usually black or brown, depending on the manufacturer) and finally the control cable (usually white, yellow or orange) that serves to transmit to the servomotor from the microcontroller the electrical pulses, which come from the multiplexer that is located connected to a microcontroller ESP32, as development board that already contains a Bluetooth communication. (Torrente Artero, 2013).

Figure 4. sg90 servomotor used in hexapod robot.

The ESP32 microcontroller as development board, is a series of low cost and low power consumption microcontrollers with integrated Wi-Fi and Bluetooth; the ESP32 series uses a Tensilica Xtensa LX6 microprocessor with dual core, there is a single core version, it is a microcontroller with a fairly high degree of complexity, as can be seen in the block diagram, it is present in many alarm systems and controllers for home automation due to the high level of connectivity offered by the same as its efficiency in terms of connections (Scmidt, Argentina). Figure 5

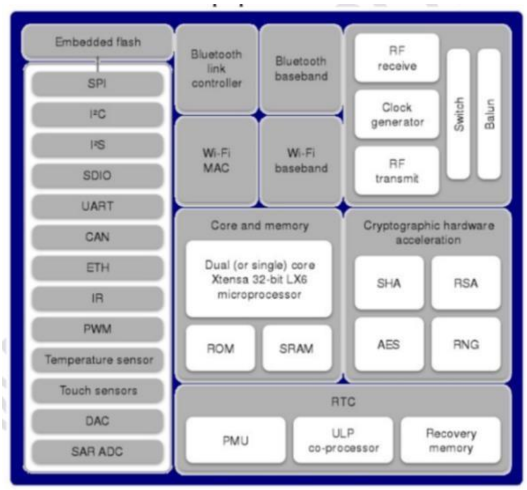

Figure 5. Block diagram of an ESP32.

The Robot program is developed in Arduino IDE, after the modeling in a CAD software, this was developed in a 3D printer where each of the parts were visualized as shown in Figure 6.

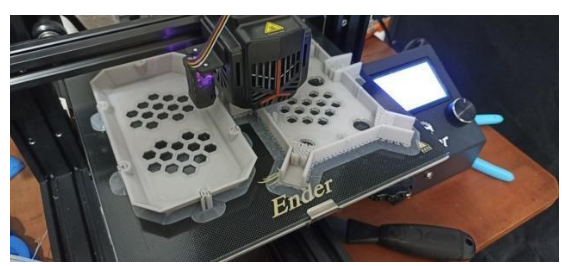

Figure 6. Prints of the hexapod parts.

To generate a movement towards the front, it is required the synchrony of the legs starting from a fixed position and starting the movement of the legs 1,5 and 3; remaining in that position to later start the movement of the legs 1,5 and 3.

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in this position to later begin with the movement of legs 6, 2 and 4, which will move further forward than the previous legs, this is known as tripod movement. Figure 7 (Ollero Baturone, 2005)

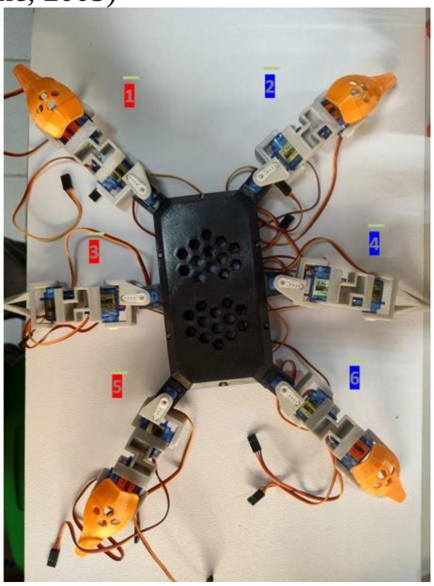

Figure 7. leg numbering distributions

In direct kinematics there are 3 equations to determine the position of a leg:

$$x = l * \cos\emptyset_1$$
$$y = l * \sin\emptyset_2$$
$$z = l_2 * \sin\emptyset_2 - l_3 * \sin\emptyset_3$$

Position equations for one leg

The kinematics equations that model the motion of a joint are determined by the Denavith-Hartemberg matrix where the joints used are involved, with this a representation of the orientation and position of each element that make up the joint of the spider leg is achieved. Table 1

Table 1. Denavith-Hartemberg matrix.

Articulation	Ø	D	a	α
1	Ø1	0	0	90
2	90	l 1	0	-90
3	Ø3	0	L 2	0
4	Ø3	0	L3	0

By performing the value substitution in the MatLab Editor application (*.M files), the following motion simulation was obtained, figure 8.
*M files), the following motion simulation was obtained, figure 8.

```
% Show the robot in the new configuration
figure(1)
h=show(robot, config);
axis([-100 100 -100 100 -100 100 -150 100]);
 % Get the line objects for each link
line_handles= findobj(h, 'Type', 'Line');
 % Set the color for each link
set(line_handles(1), 'Color', 'blue'); % Body 1
(Base)
set(line_handles(2), 'Color', 'red'); % Link 1
set(line_handles(3), 'Color', 'blue'); % Link 2
set(line_handles(4), 'Color', 'red'); % Link 2
 Adjust line width for better visibility
set(line_handles, 'LineWidth', 5);
 hold on
quiver3(10,10,10,50,50,0,0,0,'color','red',
'LineWidth', 3);
quiver3(10,10,10,10,0,50,0,'color','green',
'LineWidth', 3);
quiver3(10,10,10,10,0,0,50,'color','blue',
'LineWidth', 3);
 % Define the 88isp.88es of a cube
x = -50*[0 1 1 1 0 0 0 1 1 1 0];
y = 100*[0 0 1 1 0 0 1 1]-50;
z= 50*[0 0 0 0 0 0 1 1 1 1 1]-25;
 % Define the faces (each face is a
quadrilateral)
face = [1 2 3 4; 5 6 7 8; 1 2 6 5; 2 3 7 6; 3 4 8
7; 1 4 8 5];
 % Create the patch object patch('Faces',
face, 'Vertices', [x; y; z]', 'FaceColor',
'yellow');
hold off
 %view(0, -90); %View from above (XY plane)
%view(0, 0); %view from side (XZ plane)
 Get the transformation matrices for each
joint
T1 = getTransform(robot, config, 'body1');
T2 = getTransform(robot, config, 'body2');
T3 = getTransform(robot, config, 'body3');
T4 = getTransform(robot, config, 'body4');
T5 = getTransform(robot, config, 'body5');
T_foot= getTransform(robot, config, 'foot');
```

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```
89isp.(['x: ' num2str(T_foot(1,4)) ', y: '
num2str(T_foot(2,4)) ', z: '
num2str(T_foot(3,4))])
```

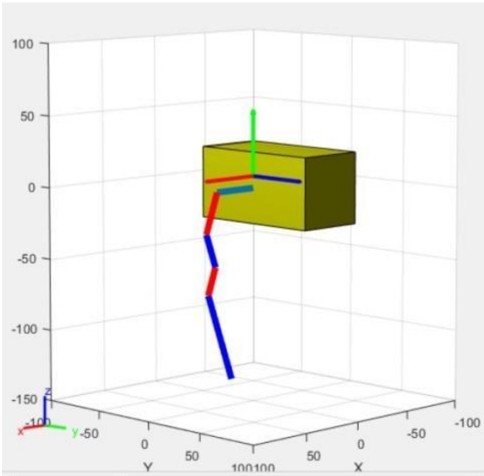

Figure 8. Simulation images in Matlab.

The electronic connection system is shown in the following figure 9.

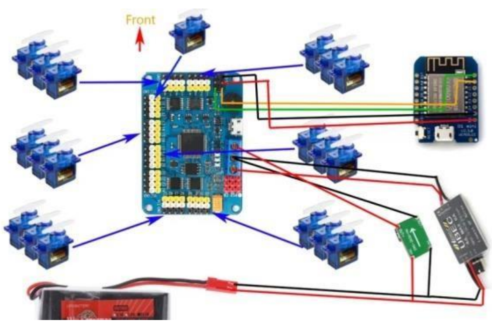

Figure 9. Connection of servomotors to multiplexer.

DISCUSSION Y ANALYSIS OF RESULTS

As a result of this research in the development of a didactic prototype of a hexapod robot, we have an equipment to perform movement practices, achieving to simulate the movement of a leg, which is replicated in each of the extremities in a synchronous way.

The kinematics obtained is limited only to the movement towards the front of the robot (protraction), in which the movement has a limit provided by the rotation angle of the SG90 servomotor, and the control of the ESP32.

One of the activities that obtained great relevance was the use of a multiplexer for the control of the 18 servomotors, achieving the synchrony of movement according to the program developed in the Arduino IDE in C language.

Figure 10. Physical obtaining of the simulated leg in Matlab.

Likewise, one of the discussions of the results was that the simulation developed in Matlab corresponded in great percentage to the movement performed physically by our prototype, both the angles and distances that were equal to the result generated and obtained, efficiently simulated the walking of the hexapod's leg.

Some authors who have already developed hexapod prototypes such as Francisco Javier Islas Vera, a student of the BUAP, which was designed for areas of difficult access, in which the results were acceptable for this purpose, this prototype contains specific work programming.

Other researchers, such as Jesús Ozuna Huerta from the University of Sonora, have developed prototypes of hexapods which are only mechanical, lacking programming or work guides at any given time.

CONCLUSIONS

With the development of this prototype, the use of direct kinematics was determined as an alternative to help generate the trajectory movements of each of the extremities of the hexapod robot, Figure 11.

Figure 11. Final prototype of Hexapod robot.

The implementation of a control algorithm for the generation of new trajectories are controlled as a first alternative by an APK, another area of opportunity that was generated is the line of research for the application of control systems, which can be an alternative from classical control to fuzzy control or intelligent control.

The execution and development of mathematical modeling by means of the Denavith-Hartemberg algorithm will allow modeling the kinematics, not only of a limb, but of all the synchronous movements of the robot already in operation.

For future research it is expected to add a new type of safety circuitry such as a gyroscope that is oriented with the magnetic north pole, likewise it can generate a working autonomy for the evasion of objects that cannot be scalable and thus decide to go around the objects to be evaded and continue its march to a defined point.

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Role Table Contribution

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Conceptualization	Carlos Enrique Maciel García
Methodology	Carlos Enrique Maciel García José María Hernández Ochoa
Administration of the project	Favio Rey Lua Madrigal
Validation	Luis Enrique Salvador Cano - Favio Rey Lua Madrigal
Editorial staff	Luis Enrique Salvador Cano
Writing- Proofreading- Editing	Salvador Cano Luis Enrique, Maciel Garcia Carlos Enrique, Hernández Ochoa José María, Lua Madrigal Favio Rey
Software	Luis Enrique Salvador Cano