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A Project Report on

Modelling and simulation of Quadruped robot.

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ABSTRACT

Robots with legs can perform complex tasks such as walking, running, and jumping. It is four times as many robots with a small number of legs to produce a triangular support polygon that allows the robot to move stable movement. Producing integrated and efficient movement of leg-powered robots requires algorithms using the natural power of the system. To measure the effectiveness of the measures produced by these algorithms, there is a need to develop a moving machine that can support such movements. A robotic platform will do to aid advanced knowledge in locomotion by demonstrating the feasibility of novel patterns of movement and strategic movement. In addition, it will facilitate the development of new control strategies to implement the required rail transport. However, statistical models of robots need to be developed to help determine important parameters as well features. The kinematic model was created by writing advanced and opposite robot kinematics. These were then used to simulate a clear flow pattern using the MATLAB system and the FUSION 360 modeling software. The leg designs created by FUSION 360 were imported into MATLAB as standard language translation files (STL). Geometry was then organized into a series of polygons in a 3-D space, and animated using homogeneous changes. Animation is used to calculate interlocking angles, foot trajectories, and visualize a flow pattern movement. Additionally, robot movement measurements were developed using Newtonian mechanics determine the strength and torque needed to hold its weight and gain mobility. By breaking the model up to its simplest parts, the torque on each member is resolved according to design parameters, reaction power, shared positions, velocities, and acceleration. The research results provide a structured model a quadruped robot that will be useful in the analysis and design of a train robot platform.

INTRODUCTION

ROBOTS WITH LEGS

Robots with legs are a constantly evolving technology that focuses on the flexible control of that robots during movement. With a better understanding of the movement of the legs and the force of movement, movement algorithms can be developed to mimic the dynamic forces of nature that mimic animal movement patterns. Finally, as the mobility of a leg-powered robot develops, so do its applications in various fields. Their skills that can be extended to rescue missions, unmanned surveys, mules, and military operations [4]. Ku to improve and balance movement, an appropriate platform that can support movement such as crawling, walking, running, and jumping must be built. Prior to designing and producing a robotic platform, behavior and the movement of legged robots should be understood by model analysis. Fourfold configuration is selected for the robot platform. Four legs are smaller than the legs needed for a robot vertical motion [5]. That is, a gait pattern where there are enough contact points to prevent a moment of robots with the body of the robot. Quadruped ones produce polygons that support the triangle during their stable movement patterns as shown in Figure 1.

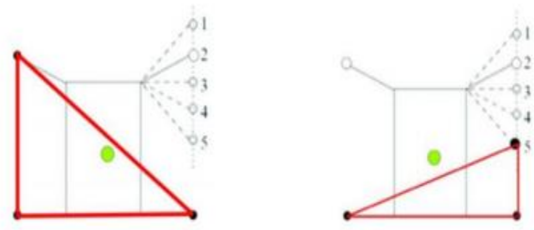


Figure 1. Comparison of different leg areas providing stable (left) and unstable support (right).

During the basic walk, only one leg is moved while leaving the remaining three legs supported body. When the center of gravity, shown in a circle in Figure 1, sits on a supporting triangle there is no stupidity the moment happens. Although unstable positions are still possible, having the potential to produce a supporting polygon during travel it makes quadruped more stable than biped and triple. Six-legged robots are known to be numerous it is stable that quadruped, however, with the addition of many organs the weight of the system increases. A lot actuators need to be controlled and introduced many other variables that make movement adjustment even more so hard. Quadruped robots provide a good balance between complexity control and stability of motion patterns.

CHOOSING A LEGGED VEHICLE

Designing a legged robot is far more complicated than a robot with wheels. There are different types of robotic leg designs with different legs. The two-legged robot follows the shape of the human leg as a base, while the quadruped robot uses the shape of a mammal's leg and the hexapod robot uses the shape of an insect leg. The robot leg has three joints, without considering the foot as it has many joints. The structure of the human leg can reach 41 degrees of freedom, while the structure of the mammal's leg can reach 12 degrees of freedom and insects can reach 18 degrees of freedom. Choosing the right type of robot configuration is very important, for any particular application. Table 1, shows the optional configuration of the robot.

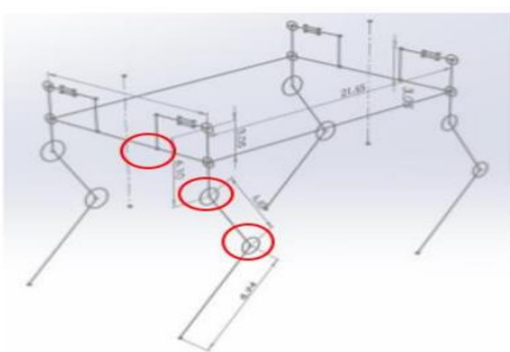
Criteria	Bipedal	Quadruped	Hexapod
Natural Design	Human	Mammals	Insects
Conceptual design		Rectangular, circular frames	Rectangular, circular, hexagonal frames
DOF	2-41	2-12	2-12
Actuators	Servos (electrical)	Servos (electrical)	Servos (electrical)
Number of actuators	Minimum of 3 per leg, Total 6 actuators	Minimum 3 per leg, Total 12 actuators	Minimum 3 per leg, Total 18 actuators
Controllers	ATMEGA, Arduino, Maestro Servo controllers, etc.	ATMEGA, Arduino, Maestro Servo controller	ATMEGA, Arduino, Maestro Servo controller
Power	Battery(12v)	Battery(12v)	Battery(12v)
Sensors	2 Force,1 Gyroscope sensors	3 Force sensors	6 Force sensors

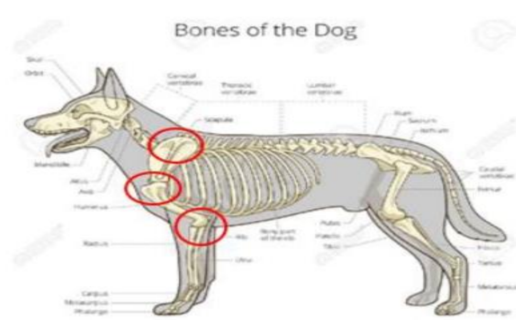
Table (1) for selection of ROBOT

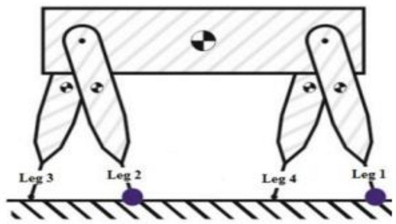
Bipedal robots have a higher level of freedom (DOF), compared to quadruped robots with a hexapod, and the number of actuators for a bipedal robot is relatively small compared to quadruped and hexapod robots. Therefore, the use of a bipedal leg structure of a quadruped robot, reduces its number of parts. Applying the same to the hexapod configuration, can make the design more complex.

Movement patterns

Another advantage of quadruped robots is their ability to mimic the patterns of moving animals. These are moving patterns can be divided into two leg support patterns, and three leg support patterns. Two-legged support pattern allows for powerful movements such as trot, speed, and jumping patterns when the two legs are paired together. Because trot pattern, legs pairs 1, 3 and 2, 4. In speed patterns, legs pairs, 1, 2 and 3, 4. In bounce pattern, pears 1, 4 and, 2, 3. The legs of the legs are shown in Figure 2. With two patterns supporting the legs, the paired legs are in a section and 180 degrees outside the section from the other pair of legs.





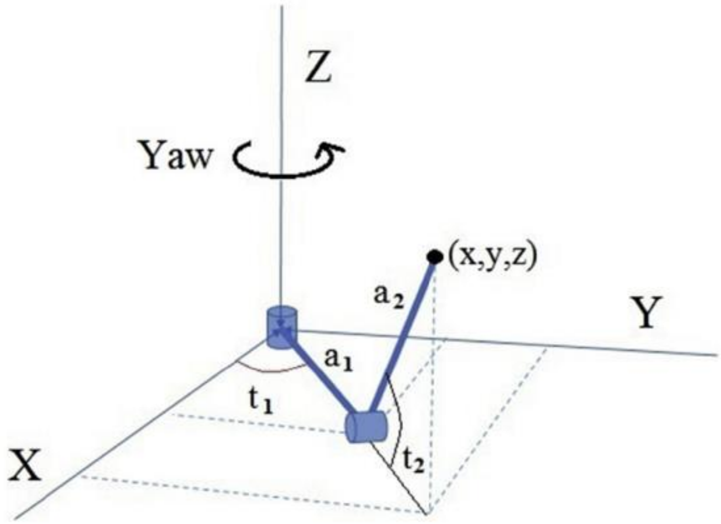


NUMBERED LEG OF QUADRUPED ROBOT

With stable walking patterns the body of the robot is supported by three legs rather than two. In these flow patterns, each the leg is activated separately. The opposite movement and rotation are examples of these patterns. The legs are inserted inside order 1, 3, 2, 4 in the opposite direction and 1, 2, 3, 4 in the roundabout. Because of the simplicity and stability of walking patterns, computer simulation was chosen. With pedestrian patterns, stable and flexible controls are easier to achieve compared to complex movements.

MATHEMATICAL MODELLING

To better understand the stable and flexible behavior of a quadruped robot, a standard quadruped robot design is modeled in two ways. First, navigation patterns are simulated with computer simulations using the Solidworks matching software and the MATLAB system. From the vibration of the movement pattern, the shape of the legs, the width of the actuation angle of the limbs, the relative speed, and the relative speed of the body can be determined. Then, the analysis was performed using Newtonian mechanics to model the robot dynamics. From the analysis performed the torque required to achieve the desired profile profile can be determined. Additional concepts such as the same mutation, advanced and opposite kinematics were used to create a quadruped robot model. For robotic kinematics it is important to be able to set up multiple communication systems and link each system to a fixed global coefficient. Homogeneous modification attaches those connecting axes by combining rotation and translation functions into a single matrix duplication. The forward and reverse kinematics have been instrumental in setting the trajectory of motion patterns and determining the critical geometry of the mechanical analysis. Equal modifications were also used to create a four-fold frame and live gait patterns in computer simulations.



MATHEMATICAL MODEL OF A LEG

FORWARD AND REVERSE KINEMATICS OF LEG:

Forward and reverse kinematics both involve using kinematic calculations to determine the location of a robot foot and to detect leg assembly. In advanced kinematics, the combined positions, or angles of each member, are known and the position of the end result can be calculated. In contrast, in reverse kinematics, the foot area is known and coherent joint positions can be obtained. Modeling the movement and position of the two-link leg model is important for the flexible analysis of the robot and the animation of the movement. The leg model of the two links is visible when representing the foot area. and the combined angles of the hip and knee, in parallel, and mean the dimensions of the thigh and shank, respectively.

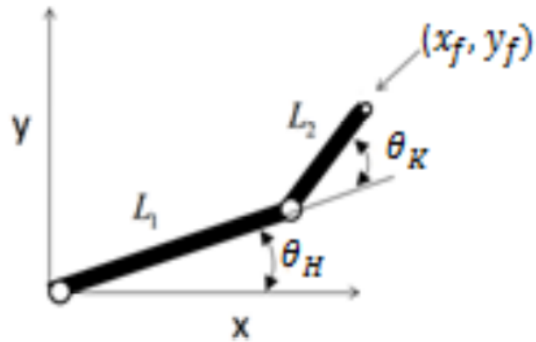


Figure 3. 2 link leg model used for deriving forward and inverse kinematics equations

Using forward kinematics for this model and known joint parameters, θ_H and θ_K, the foot position (x_f, y_f) can be calculated using equation (1) and equation (2).

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$$x_f = L_1 \cos(\theta_H) + L_2 \cos(\theta_H + \theta_K) \quad (1)$$

$$y_f = L_1 \sin(\theta_H) + L_2 \sin(\theta_H + \theta_K) \quad (2)$$

Using inverse kinematics and a known foot end effector position (x_f, y_f) is known and the joint parameters, θ_H and θ_K, can be calculated using equation (3) and equation (4). Note that θ_H is a function of θ_K therefore, θ_K, must be calculated first.

$$\theta_K = \pm 2 \tan^{-1} \sqrt{\frac{(L_1+L_2)^2-(x_f{}^2+y_f{}^2)}{(x_f{}^2+y_f{}^2)-(L_1-L_2)^2}} \quad (3)$$

$$\theta_H = \tan^{-1} \left(\frac{y_f(L_1+L_2\cos(\theta_K))-L_2 x_f \sin(\theta_K)}{x_f(L_1+L_2\cos(\theta_K))-L_2 y_f \sin(\theta_K)} \right) \quad (4)$$

MECHANICS ANALYSIS

To understand the behavior of a four-fold robot under certain static and dynamic conditions, a robust analysis of the body of the robot was performed. To analyze the following assumptions were made: all four legs are the same, contact has equally distributed masses, contact with the ground occurs in an area where the activators have a negligible weight, and all movements are planned. First, a single-leg machine analysis was performed before the quadruped robot was completely analyzed. Since all four legs are the same, the force and torque present on one leg are the same as on the other three legs. With the one-leg analysis completed, a mechanical analysis of the entire robot model was performed. In each analysis, the FBD is designed for the whole solid body and its individual components. When power and torque were shortened to about certain points in each connection, the calculations were calculated by matrix count. The calculations are solved in a standard way so that the variables are adjusted to take into account the different designs and conditions of the robot. Other calculations such as hip and knee angles and acceleration for individual coordinates were required to complete this analysis. Finally, the results of this analysis revealed the torque of each joint as a function of the reaction force applied to the foot, the acceleration and acceleration speed, as well as the known parameters such as length, magnitude, and weight of inertia links.

EQUATIONS OF QUADRUPED ROBOT

After carrying out the calculation we got the following equations for the alpha and beta in terms of X and Y coordinate of the robot leg. We added additional checks to make sure that the leg handles the input location that is impossible for it to reach. In that case the robot will try to reach the closest possible location along that point.

$$\beta = acos(\frac{a^2 + b^2 - R^2}{2ab})$$

$$M = acos(\frac{a^2 - b^2 + R^2}{2aR})$$

$$\alpha = \pi - M - atan(\frac{-y}{x})$$

Code to *Inverse Kinematic:*

Here the given figure shows the inverse kinematics block definition in **MATLAB.**

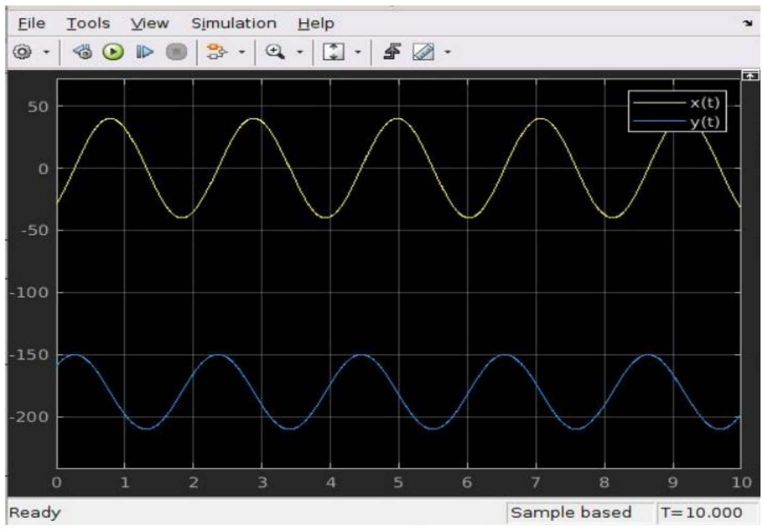
INVERSE KINEMATICS/MATLAB Function

```
function [alpha,beta] = InverseKinematics(x,y)
a = 200;
b = 180;
R = realsqrt(x*x + y*y);

if a+b < R
    alpha = pi - atan2(-y,(x+0.00001));
    beta = pi;

elseif R < a-b
    alpha = pi - atan2(-y,(x+0.00001));
    beta = 0;

else
    beta = acos((a*a + b*b - R*R)/(2*a*b));
    M = acos((a*a - b*b + R*R)/(2*a*R));
    alpha = pi - M - atan2(-y,(x+0.00001));
end
```

Trajectory Generation and working equation:

Trajectory generation is a route production process that a Joint Robot is said to follow in order to achieve a specific task. In our case the selected trajectory is the ellipse in the robot leg movement on a straight plane. Now the variables of this ellipse are in the semi-axis and the semi minor axis. In this way we can make it run smoothly on slippery surfaces and on rocky terrain.

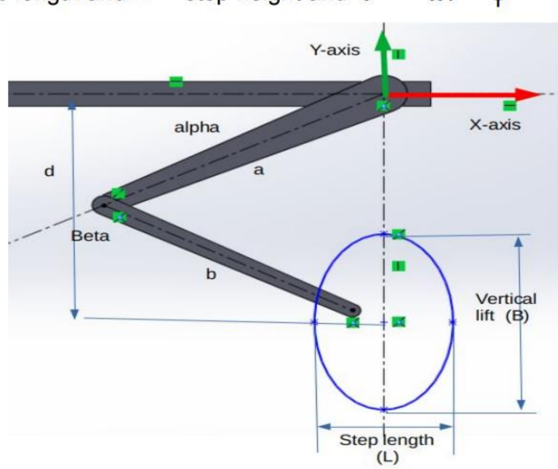
The advantages that we have with elliptical trajectory is that it can be implemented as a single function and it is simple. We use the parametric equation of the ellipse and transform it such that with increasing time it outputs X and Y coordinates of the ellipse which when followed by the robot leg produces a forward moving step. Equations below show the X and Y coordinate of the ellipse and its dependence on the time.



Elliptical parametric equation in terms of time t for x and y is:

$$X(\theta) = (L/2) \times cos(\theta + \pi)$$
$$Y(\theta) = -B \times sin(\theta + \pi) - d$$

Where L = Step length and B = step height and $\theta = \omega t + \phi$

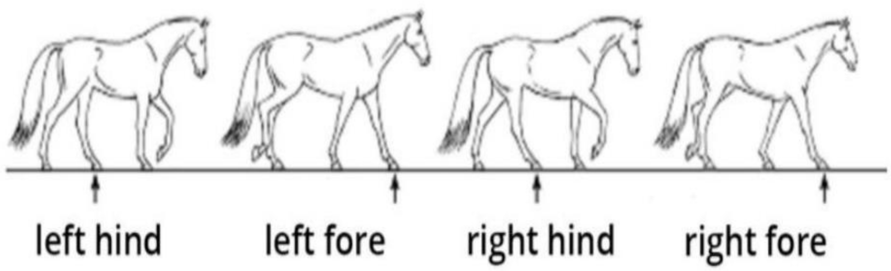


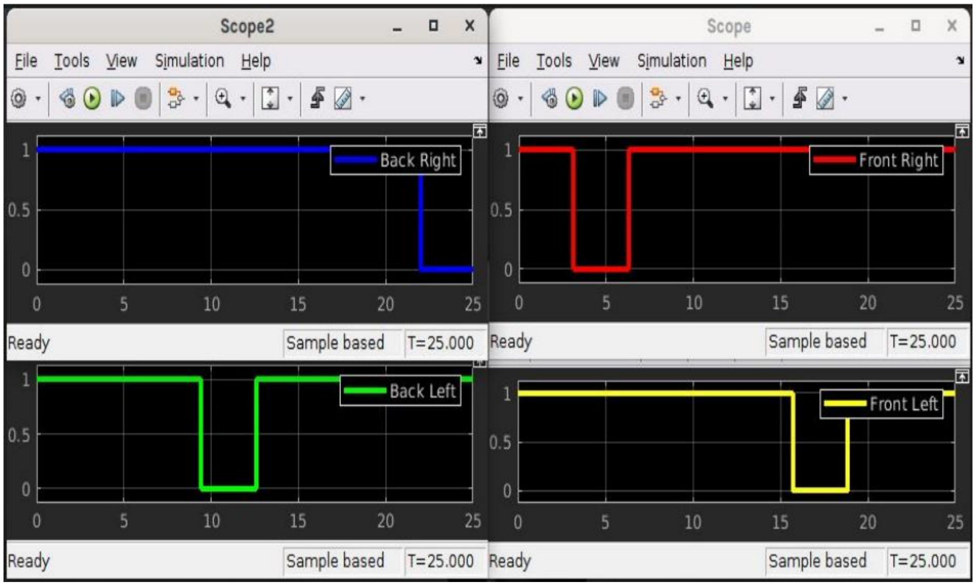
Simulating Different Gaits—

Different Gaits can be simulated by changing the ω and φ parameters.

- **Static Walking**

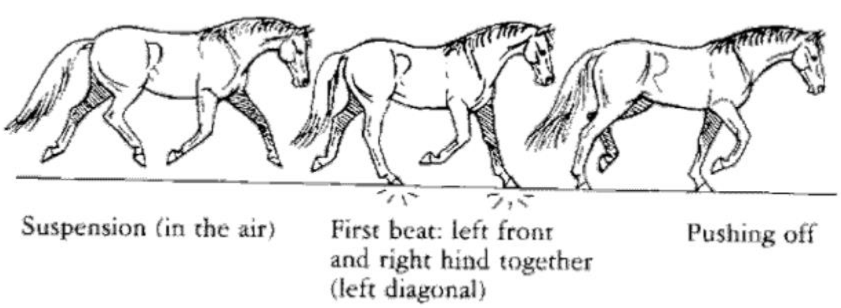
  Static walking gait is generally performed by *four legged* animals when they maneuver over hard to walk surfaces like ice, rocky mountains.

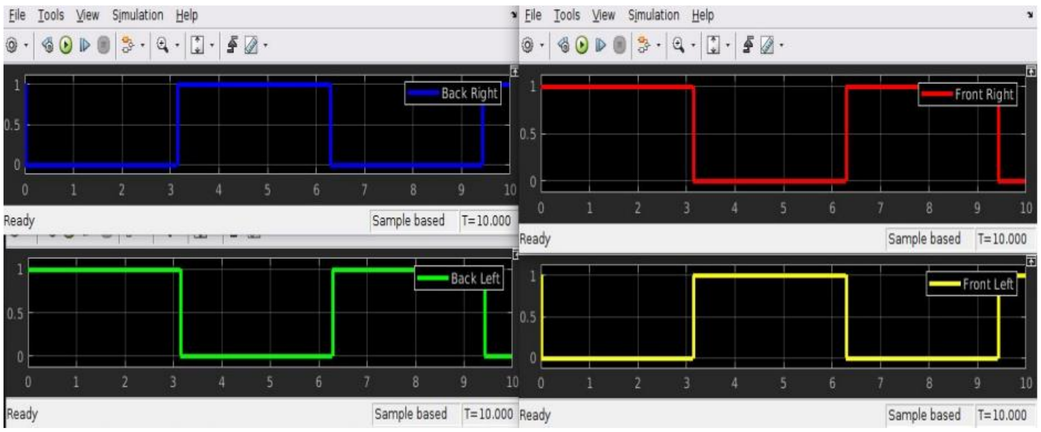




- **Trottling walk**

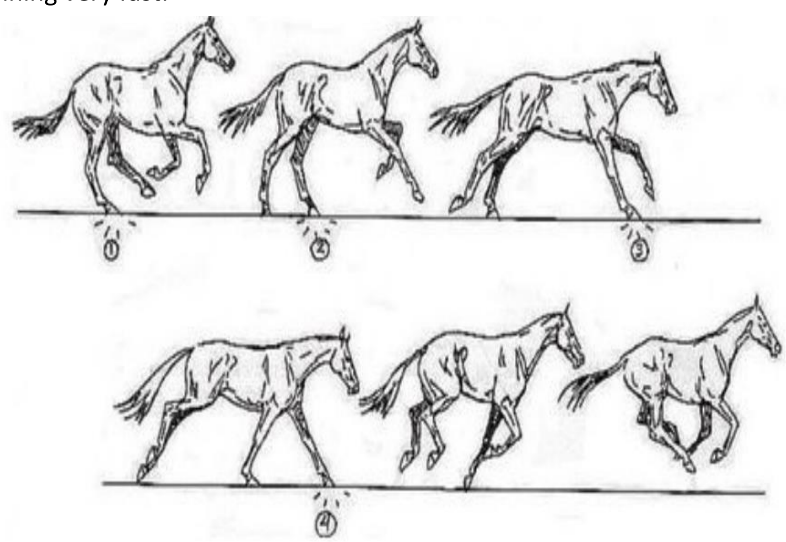
  It is seen when a robot runs at a lower speed. In this at any instant less than 3 legs are on the ground. Generally in trotting gait implementation the diagonal legs of the robot move simultaneously.



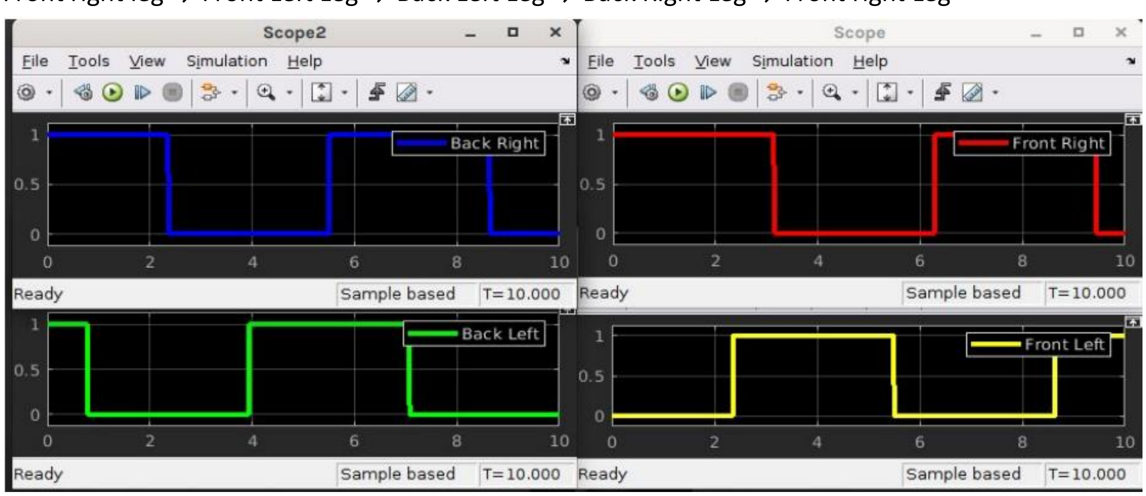


- **Galloping Walk**

  In galloping cat implementation at any instant there are less than two legs on the ground. This makes it highly dynamic in nature and is most unstable. This is generally performed by quadruped animals when they are running very fast.

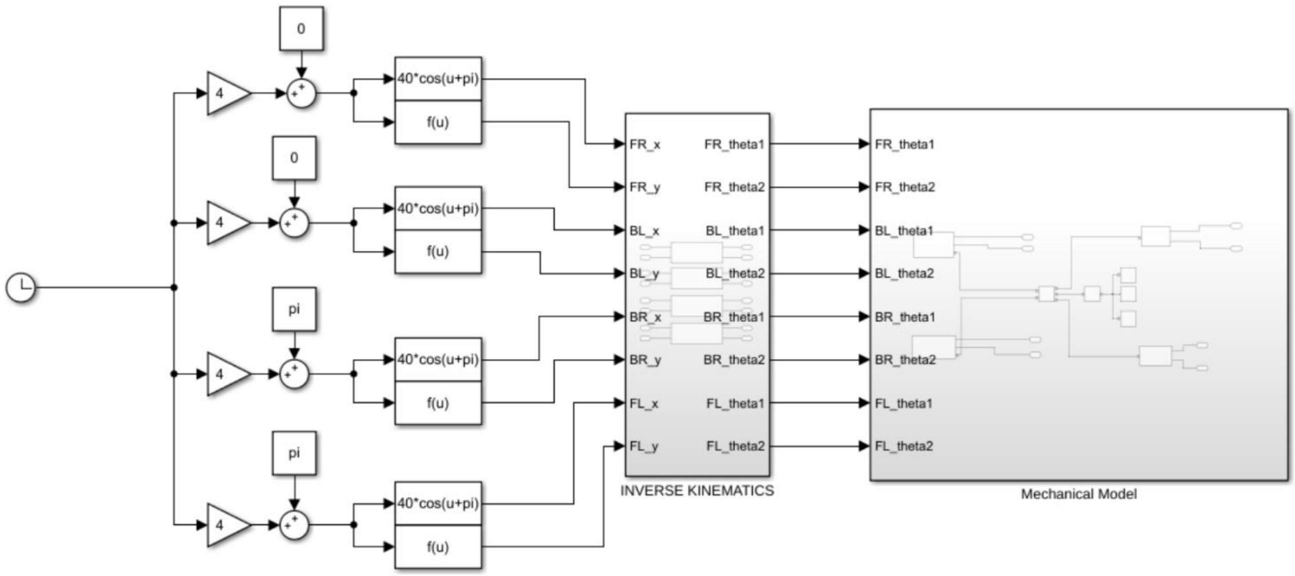


Front right leg → Front Left Leg → Back Left Leg → Back Right Leg → Front right Leg



RESULTS

Simulation of QUADRUPED Robot.



CONCLUSION

This job was very informative, and it required a great deal of patience each time we faced challenges. We understood many of the things that need to be considered before moving on to physical exercise. We found imitation to work well. We have analysed the different behaviours of the movement of the Quadruped Robots with two degrees of freedom. We also designed another model with higher levels of freedom to extend movement over time. This project can receive requests from many other people who are planning to build Quadruped Robots to analyse their models and hear and solve problems.

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