Hexapod: Animation And Projection

Course - ME735

(Computer Graphics and Product Modelling)

Guide
Prof. S S Pande
Mech Engg Dept, IITB

Mentor
Aman Kukreja

Team - 3

Shubham Agrawal
(**180040100**)

Darade Vaibhav Vinayakrao
(**180110024**)

Rateesh Sabde
(**18D170027**)

Toraskar Atharv Ravindra
(**180110089**)

1. Abstract

This document briefly discusses the trajectory of a hexapod. The main focus is put on animating the motion of the hexapod from a given point to another user-defined point. For this purpose, we have found the corner points/edges of each link as the bot moves/rotates. Then the same was plotted using a patch and plot3 command to visualize the moving bot. Moving on, we discuss perspective projection, where we aim to view the bot from a point in 3D and obtain an image in the XY plane(perspective projection). This image is then plotted.

2. Introduction

In the rapidly transforming world of robotics, researchers are looking for models/systems which can be introduced in the real world, so scientists are concentrating more on the real-life entities only. If we can mimic the motion of any real-life object(field of Bio-mimicry specifically focuses on this only) and get a moving robot(whose motion will be complex but will be smooth and of use), it can be used in several fields like medicine, materials science, nanotechnology, and industrial design. Prominent examples of biologically inspired locomotion which are being concentrated nowadays are hexapods(six-legged robots) and octopods (eight-legged robots). Here we will be looking into hexapods. Their Degrees Of Freedom(DOF) vary from one to three per leg, depending on the complexity of motion. Both of these can be used to navigate over uneven terrain or obstacles on the ground. So it is clearly seen that these are very important and useful forms of robot and will have wide use as a human assist or on its own, in different taxing activities where humans face life and death dangers.

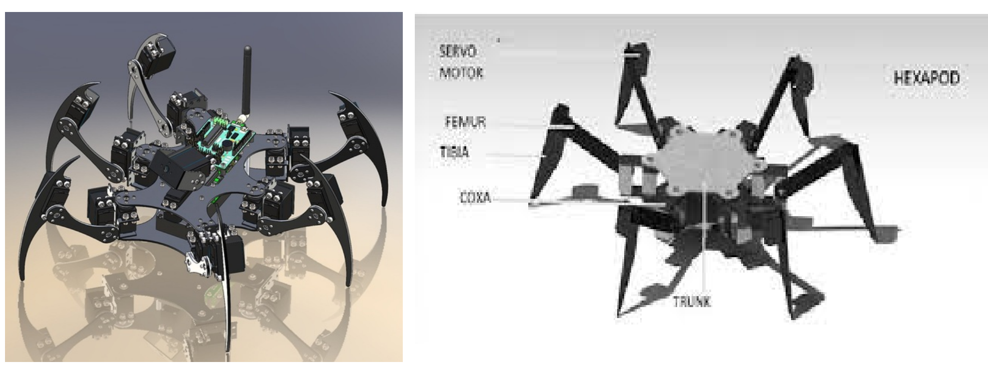

Fig 1: Hexapod Structure

Hexapod consists of different subsystems which must work in sync with each other to give the desired movement. As the name suggests, a hexapod must have six legs and the main body(hexagon). Each leg has three degrees of freedom. We will model the one leg first, and then it can be transmitted to all other legs giving some phase difference(has explained in detail later).

We study the trajectory of the foot position of the leg and the position of the point at which the leg is attached to the body is known. So to get the complete configuration of the leg, inverse kinematic analysis is done on the trajectory (refer to 3.1 section for detail). To move from the initial position to the final position we first rotate the base in the direction to go and then move in that direction with a constant speed. From the GAIT pattern, we know how the motion of each leg is coupled with the base (detailed description in sections 3.1 and 3.2).

This leaves us with complete information about the hexapod shape and configuration at different time steps, then comes the major and important part of the projection i.e., how will the observer perceive the motion of our hexapod when it is walking. To get the exact feel of real-life movement, we have used the perspective projection on the XY view plane with user-defined Centre of Projection (COP), detailed description in section 3.3.

3. Algorithm Description

3.1. Hexapod Trajectory

Like most biological creatures walk by alternatively lifting and placing the legs from and on the ground, in legged locomotion, we go with a very similar idea. The entire motion is cyclic in nature, with the same motion being repeated for each leg with a phase difference. To understand more of this, we first focus on the movement of a single leg over a cycle.

The motion of a leg can be divided into two parts, namely, the swing phase and stance phase. In the swing phase, the foot is not in contact with the ground and is moving fast in the direction of motion of the bot to place a foothold at the next location, which is further in the direction of motion. In the stance phase, the foot remains in contact with the ground and provides the force necessary to push the bot forward and balance its weight.

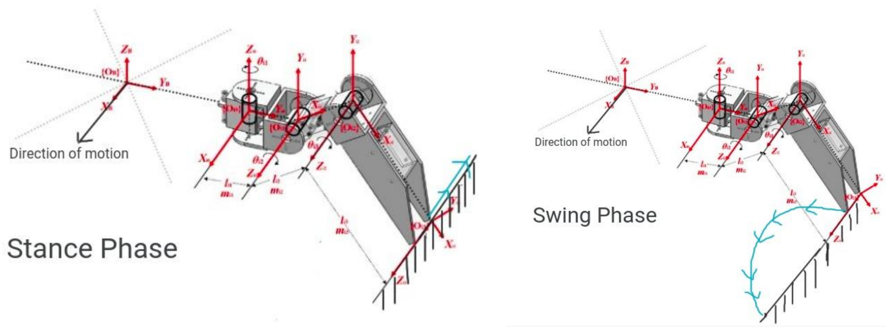

Fig2: The motion of foot wrt to base in swing and stance phase

The above figure shows the motion of the foot from the frame of reference of the base of the bot. During the swing, the foot moves faster than the base in the direction of motion of the bottom place foot. While instance, as the foot contact is stationary wrt to the ground, it appears to be moving backward wrt to the base. If we combine these two motions, we get the motion of the legs over each cycle. For our case, we considered the swing trajectory to be sinusoidal and the stance trajectory to be a straight line.

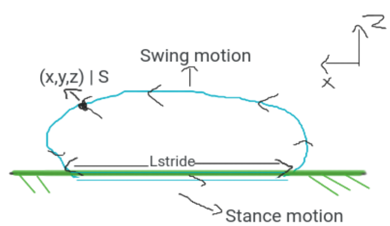

Fig3: Cyclic motion of each leg

To define the motion of the entire bot, every leg follows the same trajectory with a certain phase difference which creates an alternate cycle where some legs are in contact with the ground while others are in swing, ensuring the overall stability of the bot. Deciding on the phase difference between the legs constitutes a gait pattern. From the three gaits shown below, we have used ripple gait.

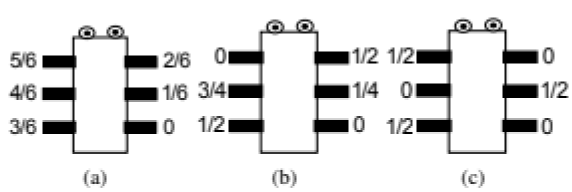

Fig4: Relative phases for hexapod gaits a) Metachronalgait b) Ripple gait c) Tripod gait.

3.2 Deriving Discrete points

To properly define a body, we should know as many params as the degrees of freedom of the object. In this case, Hexapod has 24 degrees of freedom. Three degrees of freedom for each of the six legs and 6 degrees of freedom of the base. In the context of this document, we are concerned only about the x,y, and yaw of the base as only in-plane motion on even terrain has been animated. Hence it was needed to find these 21 params.

Having studied the hexapod motion, the trajectory of the foot of each leg is known with respect to the base. The three joint angles for each leg could be derived from the trajectory using inverse kinematics. If the initial base position is provided, the future pose can be estimated based on how much the legs have moved (The base moves in the opposite direction to the legs instance).

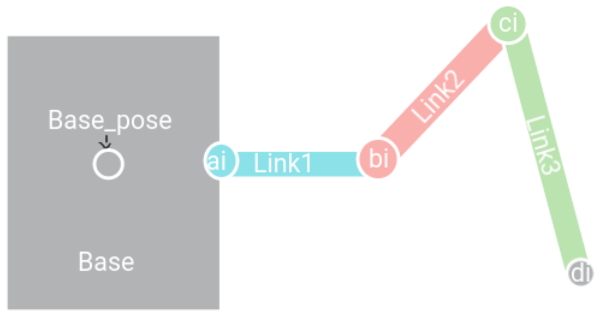

Fig5: Nomenclature used for describing Hexapod

Position of ai (i=[0:5], denotes the leg number), is fixed with respect to the base_pose as it is defined by the dimension of the base of the hexapod. Once ai is known, it is possible to get the position of bi using link1 length and the joint1 angle. Similarly, ci and di were described in terms of bi and ci, respectively, using the respective link lengths and joint angles.

At this point, we know the position and orientation of each leg with respect to the base. These positions are expressed in the frame of the robot. When the heading and position of the robot change, these points are subjected to appropriate geometric transformation, that is, rotation about the Z-axis and translation by the [Xbase, Ybase]. At this stage, the robot shape is completely determined in discrete points.

To make the robot move, we need to iterate through the joint angle values found by inverse kinematics of trajectory and keep updating the base_pose to see the hexapod moving/rotating in the desired direction.

3.3 Perspective Projection

Perspective projection or perspective transformation is a linear projection where three-dimensional objects are projected on a picture plane. This has the effect that distant objects appear smaller than nearer objects. It also means that lines that are parallel in nature (that is, meet at the point at infinity) appear to intersect in the projected image, for example, if railways are pictured with perspective projection, they appear to converge towards a single point, called the vanishing point.

Photographic lenses and the human eye work in the same way. Therefore perspective projection looks most realistic. Perspective projection is usually categorized into one-point, two-point, and three-point perspectives, depending on the orientation of the projection plane towards the axes of the depicted object.

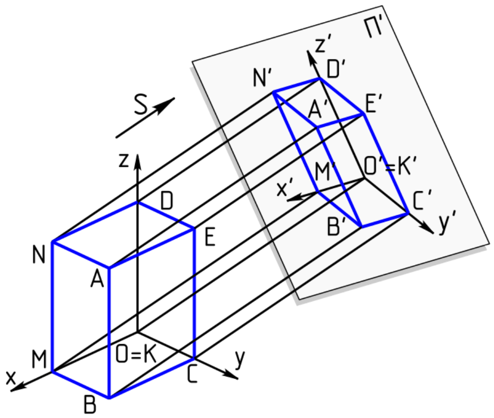

Fig6 Geometric projections

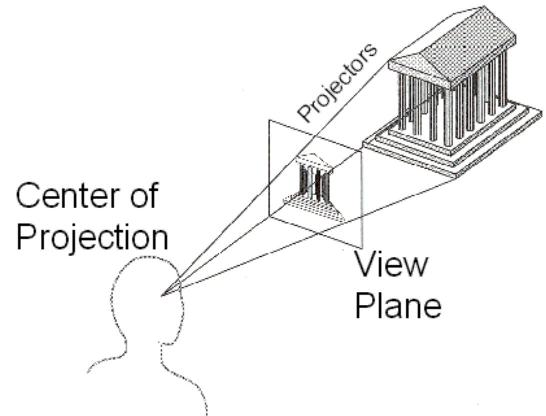

Fig7: Perspective projection

Once all the link endpoints have been computed, they are then transformed using the perspective projection. Function, with the center of projection being at (x_c, y_c, z_c) specified by the user.

$$x_p = x_c + \left(\frac{-z_c}{z_1 - z_c}\right) * (x_1 - x_c) \qquad y_p = y_c + \left(\frac{-z_c}{z_1 - z_c}\right) * (y_1 - y_c)$$

The obtained points are plotted on the x-y plane to get the perceived image as seen from the given point.

4. Results

In this project, we could successfully build a walking model of the hexapod with 21 Degrees of Freedom(DOF), in which the hexapod walks from any given point to another user-defined point. We have animated the model on MATLAB using the plot3 function. We also projected this motion on a 2D plane using perspective projection. The two animations are rendered as videos.

1) 3d_video_link , 2) pers_projection_video_link

5. Conclusion

- In summary, we have successfully calculated the hexapod base and actuator trajectories and animated the followed path on MATLAB
- The hexapod can successfully translate and rotate freely to move from any point to any other point in the plane.
- The perspective projection of the moving bot about any point can be obtained.

References

- Hexapod Locomotion: a Nonlinear Dynamical Systems Approach
- Optimization-based motion planning for legged robots, ETH Zurich
- “Modern Robotics: Mechanics, Planning, and Control," Kevin M. Lynch and Frank C. Park, Cambridge University Press, 2017
- “Robot Dynamics and Control,” Mark W. Spong, Seth Hutchinson, M. Vidyasagar, Wiley(2004)
- Projection Transformation, ME735 Fall 2021, IIT Bombay
- https://in.mathworks.com/help/matlab/ref/patch.html
- https://in.mathworks.com/help/matlab/ref/plot3.html
- https://in.mathworks.com/help/matlab/ref/videowriter.html