Creating Quadruped from Sratch *

S. V. Shah
Robotics Research Center,
Assistant Professor
Department of Mechanical Engineering
Indian Institute of Technology Jodhpur
Rajasthan, India
surilshah@iitj.ac.in

S. P. Yadav
Department of Electrical Engineering
Indian Institute of Technology Jodhpur
Rajasthan, India
yadav.1@iitj.ac.in

S. Jaiswal
Department of Mechanical Engineering
Indian Institute of Technology Jodhpur
Rajasthan, India
jaiswal.1@iitj.ac.in

ABSTRACT
This paper presents presents a approach for developing a quadruped from sratch. Performance of legged robots can to a great extent, be independent of the uncertainty of the ground.

Keywords
Quadruped, Static walking, Crawl gait.

1. INTRODUCTION

Legged locomotion of robots is very important. It allows robot to navigate the unknown and uneven terrain. Robots with the capability to navigate in a cluttered environment can be used in many situations like disaster management, exploring unknown areas, completing a task in hazardous areas etc. State of the art techniques depend upon modeling of robot and environment and then devising sophisticated control laws to make robot navigate in an environment. But this is dependent on robot dynamics and how accurately it is modeled. This lead to very inefficient walking methods. Recent developments in the area of reinforcement learning can be exploited to make a robot learn to walk like a toddler. Once a learning is complete, it can navigate on learned environment as well as it can generalize to new environments. This is a very general method, therefore same program can be used on different robots and they all can learn simultaneously and from each other. ([1], [2], [3]).

2. STABILITY OF QUADRUPED

Legged robots are inspired by terrestrial animals. They are broadly classified, based on no. of legs. Ex-biped (2 legged), quadruped (4 legged), hexapod (6 legged) etc.

Stability means balancing of the robot. There are two types of stability Static stability and Dynamic stability. Robot is statically stable when projection of Centre of mass (COM) on horizontal plane lies inside support polygon formed by foot contacts. In other words no extra force or moment is required to balance the robot. Whereas robot needs to be dynamically stable if COM lies outside support polygon. For a given configuration of robot, Stability Margin is of two types longitudinal stability margin and static stability margin. Stability Margin S_m, is defined as a minimum distance of the vertical projection of the COM to the boundaries of the support polygon in the horizontal plane 3. Longitudinal stability margin S_l, is defined as a minimum distance of the vertical projection of the COM to the boundaries of the support polygon in the horizontal plane along the direction parallel to motion of COM 8. The main body of the quadruped is modelled as rectangle and four legs are attached at corners.

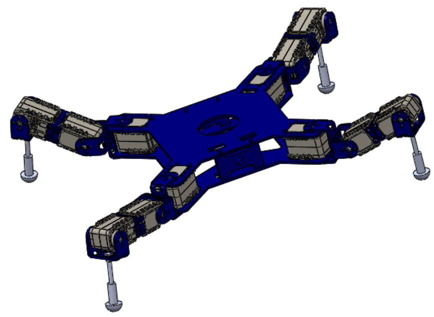

Figure 1: Quadruped

3. GAIT: WALKING PATTERN

Pattern of movement of the limbs of animals is called gait. Variety of gaits are used by animals. Gaits are generally classified as symmetrical and asymmetrical In a symmetrical gait left and right leg of a pair alternate, while in a asymmetrical gait, the legs move together. Inexing of legs is done as follows, front left (1), front right (2), rear left (3), rear right (4) Quadruped can lift only one leg at a time to be statically stable while walking. Therefore total no. of possible gaits are 6 = (4-1)!, considering leg no. 1 is always lifted first. These are called as creeping gaits. Gaits which give maximum stability for walking along one particular direction are called crawl gaits. If the walking direction is x then the crawl gait is 1-4-2-3 (X-crawl) . Gait can be charac-

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http://dx.doi.org/10.1145/2506095.2506118

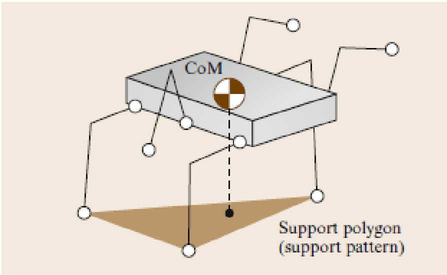

Fig. 16.21 Support polygon (support pattern) of a multi-legged robot

Figure 2: Support Polygon of a multi-legged robot

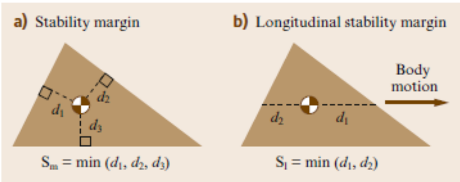

Fig. 16.22a,b Definition of stability margins

Figure 3: a)Stability Margin b)Longitudinal Stability Margin

terized by two parameters, duty factor (BETAI) and phase (PHII) of each leg i.

DEFINE BETA AND PHI Gait which has maximum longitudinal stability margin is called wave gait. BETAI <1 BETAI >=0.75 CONDITIONS In this paper wave gait was selected and various duty factors were used for simulation. Considering step size to be L (stride length), the cycle time T and duty factor B Walking speed can be calculated as follows

FORMULA

Taking stride length as 14 cm and duty factor of 0.75 with 4 sec of cycle time speed would be [VALUE]

4. KINEMATICS OF LEGS

DH parameters of the quadruped is as follows

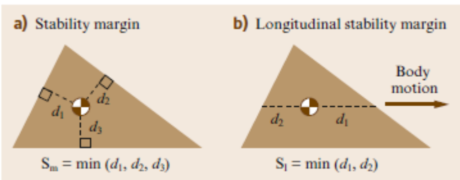

Fig. 16.22a,b Definition of stability margins

Figure 4: Longitudnal Stability Margin

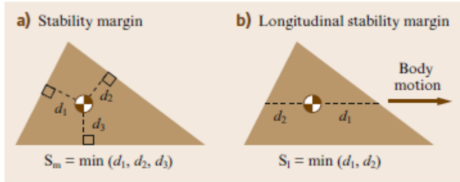

Fig. 16.22a,b Definition of stability margins

Figure 5: Longitudnal Stability Margin

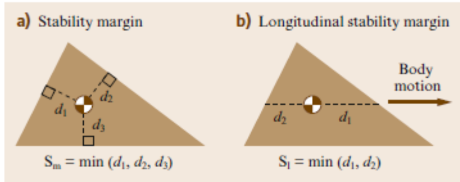

Fig. 16.22a,b Definition of stability margins

Figure 6: Longitudnal Stability Margin

DHDHDHDHD FIGURE

Coordinate frame attached to the ground, positive Z-axis of which is defined along the direction opposite to gravity. X and Y axis are arbitrarily chosen on plane surface following the right hand thumb rule. One frame is attached to centre of the main body where positive Y-axis is pointing towards front direction. X- axis is towards right and Z-axis is following the right hand thumb rule. This frame is called body frame. Four frames are attached to the body at the contact with tibia as shown in figure

Using DH parameters and coordinate transformations we can calculate foot position of a leg as given below

FK EQUATION

Inverse Kinematics Forward kinematic model define above gives positions of links and foot location based on joint angles. The IK problem consists of determining joint angles if foot location is given. Geometrical approach was used to find joint angles from foot position. Theta 1 (angle between Coxa and Femur) can be calculated as given below

THETA 1

Now theta 2 and theta 3 can be calculated applying cosine law . Finally theta 3 was found using given equation EQN

5. ANALYSIS OF WORKSPACE

To find various parameters such as height of COM, stride length etc. quadruped structure was thoroughly analyzed. To find workspace of foot locations of a leg joint constraints were used. Each joint was allowed to be in particular range based on physical constraints of quadruped as well as due to torque constraint of motors. It was assumed that in given joint ranges quadruped can lift its weight and move forward. The height of COM should be such that it gives maximum workspace for leg (i.e. range of foot locations of leg

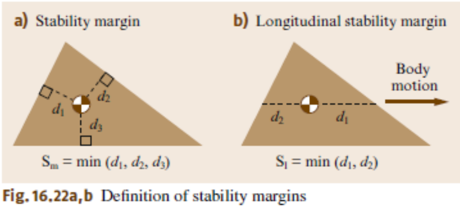

Figure 7: Longitudnal Stability Margin

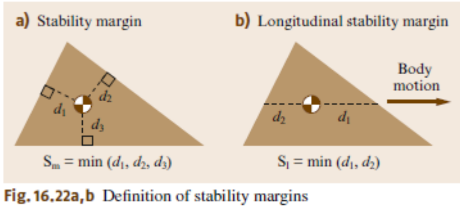

Figure 8: Longitudnal Stability Margin

should be maximum). Also leg foot workspace should be continuous (convex polygon) as it would allow symmetry in all directions. Since quadruped height can deviate from selected height due disturbances. Therefore it workspaces of leg should not differ much while changing height of COM. We plotted workspace of a leg for different heights and selected 9cm as good choice based on above reasons. IMAGES Then from given workspace of leg we selected rectangular workspace was selected for further analysis. Optimal stride length was found based on following reasons As large as possible for large speeds Leg trajectory should be symmetrical in X and Y direction. Good manipulability Trajectory of leg as far as possible from boundaries of foot workspace.

Finally initial location of foot was selected at intersection X and Y strides

6. WALKING ALGORITHM

This section would explain about walking of quadruped with constant velocity. Considering direction of motion to be positive Y-axis. Velocity of COM is Vcm (0 x_cap,Vcm y_cap, 0 z_cap) which is constant during the motion. Gait cycle consists of two phases support phase and transfer phase. In support phase foot is in contact with the ground while in transfer phase foot is lifted and moved to next foot location. In support phase foot is having no relative motion with respect to ground while it is moving with velocity âĂŞVcm with respect to body frame. Trajectory of foot is planned with respect to body frame and then transferred to ground frame. Since velocity of foot in support phase is fixed, so we only need to plan trajectory of foot in transfer phase. The problem of designing trajectory consist of movement of foot from initial foot location to final foot location. Assuming direction of motion is along Y- axis of body frame then foot moves from (x1,y1,z1) to (x1,y1+Ls,z1). One important parameter for designing foot trajectory is foot clearance as shown in figur FOOT CLEARANCE FIGURE Foot trajectory in z direction was implemented using cosine function as given below EQUATION DIAGRAM Three types of trajectories were analyzed during transfer phase along Y direction. 1. Linear âĂŞ 2.Cosine âĂŞ 3.Quintic âĂŞ

Finally quintic polynomial trajectory was selected along Y direction due to above mentioned reasons.

7. SIMULATION RESULTS

Design of quadruped Kinematically simulated Collision detection Failure âĂŞ Distance of foot position from body, perpendicular to direction of motion should be selected appropriately to overcome any discripancies.

8. CONTROLLING QUADRUPED USING ROS

Quadruped was controlled using ROS.

9. DISCUSSION AND CONCLUSION

A approach has been shown in this work to create a quadruped from sratch. Stability of any legged robot is explained. Crawl gait was used as walking algorithm for plane surface. Parameters like height of COM, stride length etc. were optimally selected based on analysis of workaspace of leg. Different leg trajectories were compared and finally quintic polynomial trajectory was selected based on effectivness. Kinematic simulation of quadruped was done to confirm above work. Quadruped was designed in solid works and was simulated to check collisions. Finally a real quadruped was controlled by driving dinamixel motor through ROS. Quadruped wwas able to walk as same in simulation.

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