Multiple degrees of freedom significantly complicate the control problem & result in higher weight due to high no. of actuators;

Thus robot with single - DOF is designed (jumping motion)

This robot relies on linkages that provide direct kinematic link b/w actuation & end effec-tor.

Robot testing rig → it will allow data to be (position & orientation) collected accurately without relying solely on accelerometers

Specifications:
→ bot must jump twice its height.
→ some leg which moves linearly.

Mechanism:
→ Pantograph, this allows the foot to stay in contact with the ground for long periods of time with a fixed point of contact while also having a direct kinematic relationship b/w input and output motion.

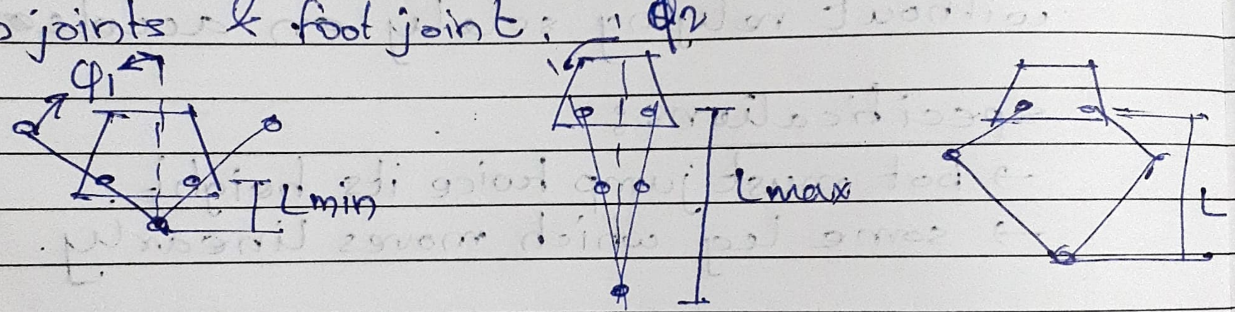
In order to generate linear motion, the upper leg segments must rotate in a coordinat-ed manner such that the angle bisector b/w the legs remains vertical for all leg rotation angles.

→ physical connection & transmission system controlled by a single motor.
· This simplifies the controller by linking leg motion directly to rotation of a single motor.

✪ Kinematics:

Hip joint: defined to rotate 180° in an arc resulting in legs moving b/w parallel & anti-parallel configs.

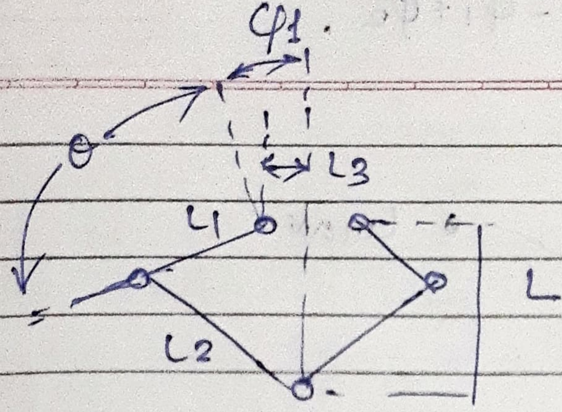
Leg extension is defined as variable L which is the vertical dist. b/w the axis of the hip joints & foot joint.

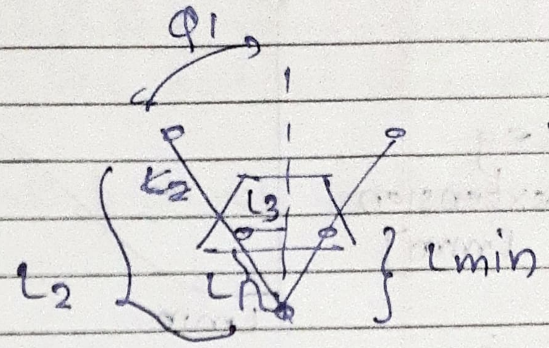


choosing system variables:

L_1 is length of upper leg segment.
L_2 lower length segment.
L_3 dist. b/w hip joint & axis of symmetry
θ is used to determine the config of leg.

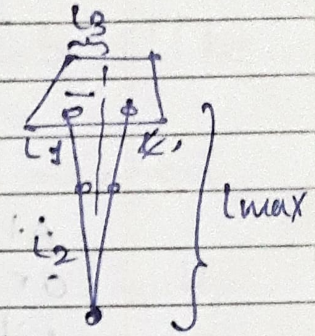
The leg extension L is a function of θ & geometric parameters.





$\therefore$

$$\varphi_1 = \sin^{-1}\left(\frac{L_3}{L_2+L_1}\right) \quad \text{—— (1)}$$



$$\varphi_2 = -\sin^{-1}\left(\frac{L_3}{L_2+L_1}\right) \quad \text{—— (2)}$$

$$L_{min} = \sqrt{(L_2-L_1)^2-(L_3)^2} \quad \text{—— (3)}$$

$$L_{max} = \sqrt{(L_1+L_2)^2-L_3^2} \quad \text{—— (4)}$$

→ Upper legs will be linked by a transmission which ensures the foot remains in a linear path. ∴ Gearing is necessary.

Gear ratio b/w the motor and transmission will be defined as G.

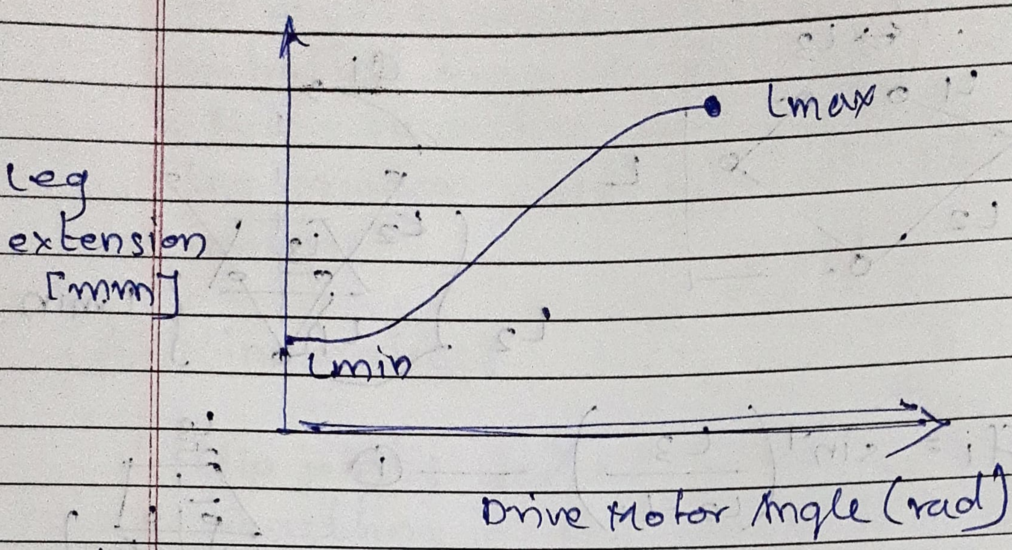
Now, $$\theta = \frac{\theta_m}{G} \quad \text{—— (5)}$$

θ_m is the angle of rotation of motor

$$\therefore L = \sqrt{L_2^2-\left(L_3+L_1\sin\left(\frac{\theta_m}{G}+\varphi_1\right)\right)^2} - L_1\cos\left(\frac{\theta_m}{G}+\varphi_1\right) \quad \text{—— (6)}$$

at l_{min} $\theta = 0$

l_{max} $\theta = \pi - \varphi_1 + \varphi_2$



At l_{min} & l_{max}, the slope is close to 0. or the change in motor angle (θ_m) has little effect on motion of leg.

At the middle, the slope is large, or, a small change in θ_m causes large leg motion.

Advantage: In Jumping →

if the bot is landing from a jump, large amnt. of force is required to reverse the momentum & slow it.

Assuming the bot lands with leg at low extension, the flat slope at l_{min} means that for low output of torque, the force gets magnified. ~~Thus decrea~~ or is much more. ∴ force is magnified

Thus decreasing amnt of torque the motor must provide.

→ The steeper slope allows for high speed output. This means that the motor speed can be ~~lo~~ slow such that the output torque of motor is high.

Thus the bot can achive high vel. for takeoff.

coordinate System:

Location & orientation of the robot will be defined in 3-D space.

The position of foot of bot is defined using x, y, z.

z is 0 when the foot is in contact with the ground. This location is taken as the origin for a spherical coordinate system where R represents the dist. from the origin to the COM of bot.

Leg Motor Specification:

Assuming force from foot is const.

→ choosing motor ~~from~~ based on min. torque means that output force will be much higher when the leg is near min/max extension.

The work input to the system is provided as torque from the drive motor that is translated into linear motion of the foot by pantograph mechanism.

Work input = P.E of system

$$F_o(l_{max} - l_{min}) = mgz_{max}$$

z_{max} = max. jump height

$$\boxed{z_{max} = \frac{F_o(l_{max} - l_{min})}{mg}}$$

→ as this is relative to the height of the bot, making the mechanisms as compact as possible as to min. the the height of bots body.

To calculate output force,

$$\tau_m \times \delta\theta_m = F_o \times \delta l$$

$$F_o = \frac{\tau_m}{\frac{\delta l}{\delta\theta_m}}$$

$\left(\frac{dl}{d\theta_m}\right)$: relates to leg extension to motor angle

→ Thus at the middle of the curve; slope in max. thus F_o is min.
or, the drive motor will operate at relatively low speeds meaning that the torque output will be equivalent to stall torque

★ A motor with twice the ~~stall~~ calculated stall torque τ_{ms} is selected.

$$\tau_{ms} = \frac{mgz_{max}}{(l_{max} - l_{min})} \times \left(\frac{\delta L}{\delta \theta_m}\right)_{max}$$

slope is calculated using a numerical approximation of slope

$$\bar{\theta}_m = \frac{G}{2}(\pi - \varphi_1 + \varphi_2)$$

$$\left(\frac{\delta L}{\delta \theta_m}\right)_{max} = \frac{L(\bar{\theta}_m + \Delta) - L(\bar{\theta}_m - \Delta)}{2\Delta}$$