Stewart Platform

Omar, Namrita, Abhishek

Problem Statement

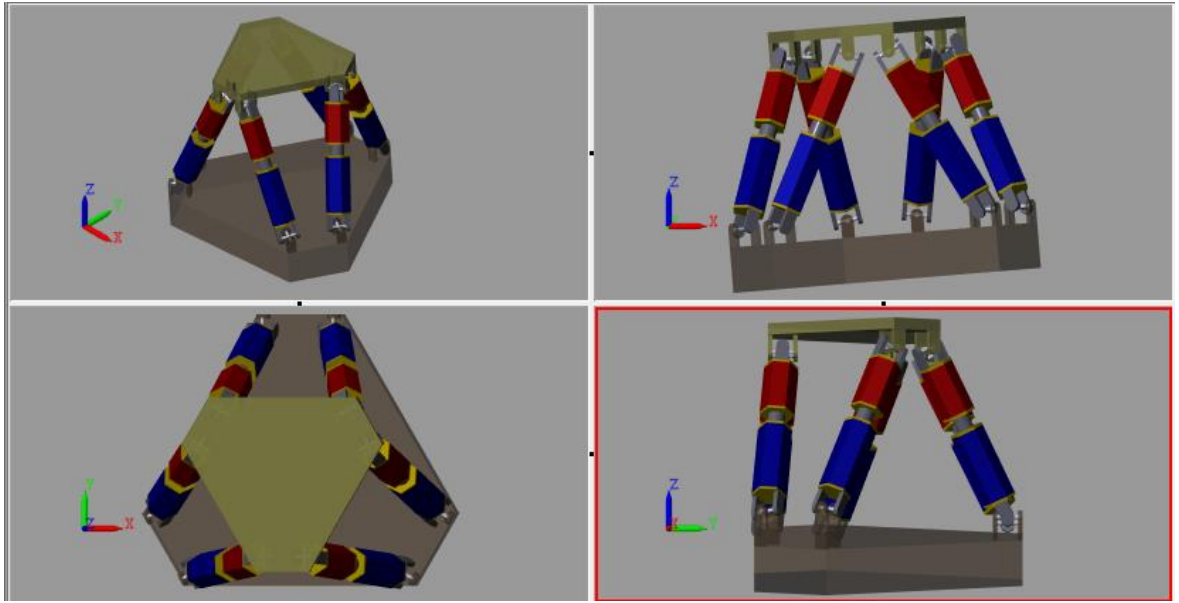
Maintain the stability of a pool table

on a cruise ship

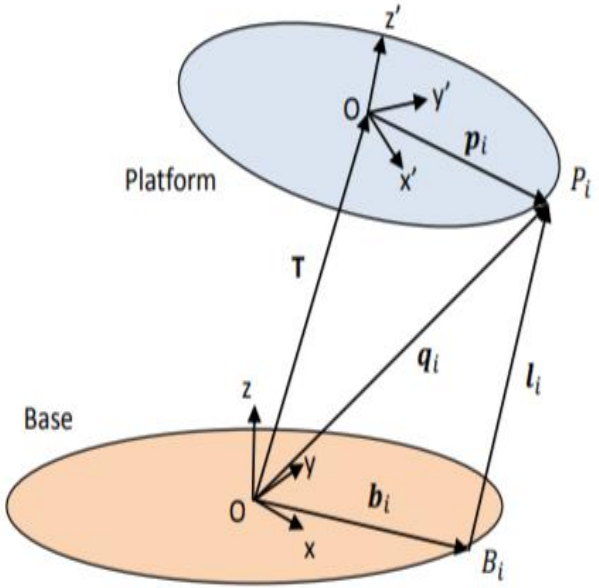
Solution

- Use the concept of a stewart platform in reverse
- Consists of a base plate and top plate connected by 6 linear actuators
- Gives top plate 6DOF
- Base plate will be rigidly attached to the ship

Concept: Keep the top plate perpendicular to the gravity vector



Modeling Of The Stewart Platform



Inverse Kinematics-> Relatively Simple!

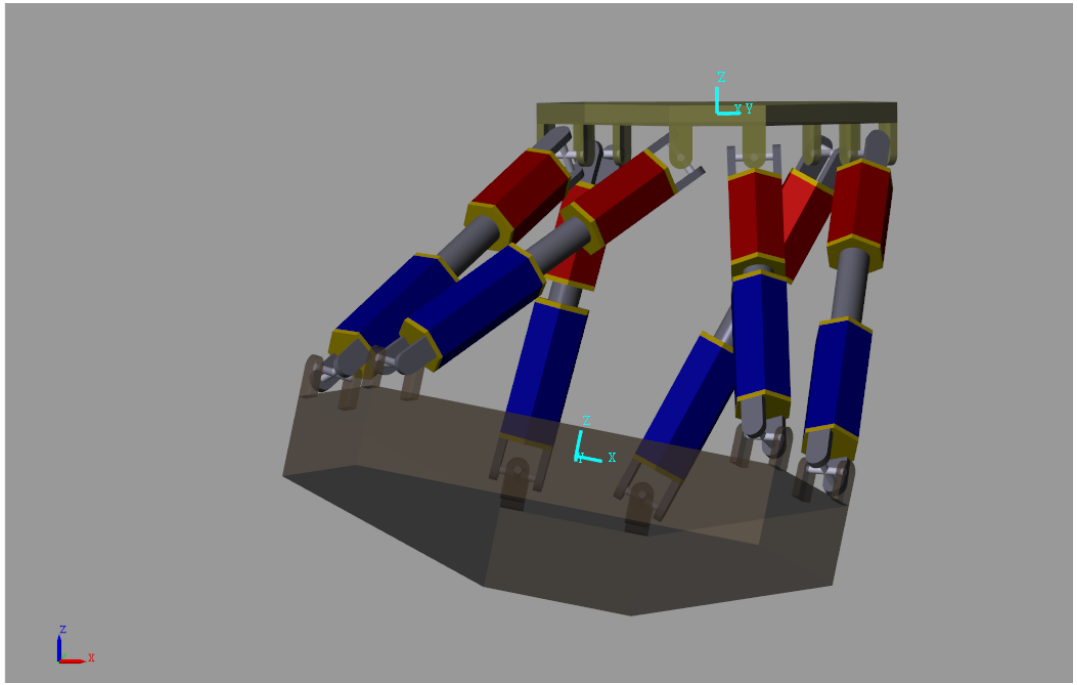
bi+li=qi

li- Leg Length

$$q_i = \mathbf{T} + {}^{P}\mathbf{R}_B \cdot p_i$$

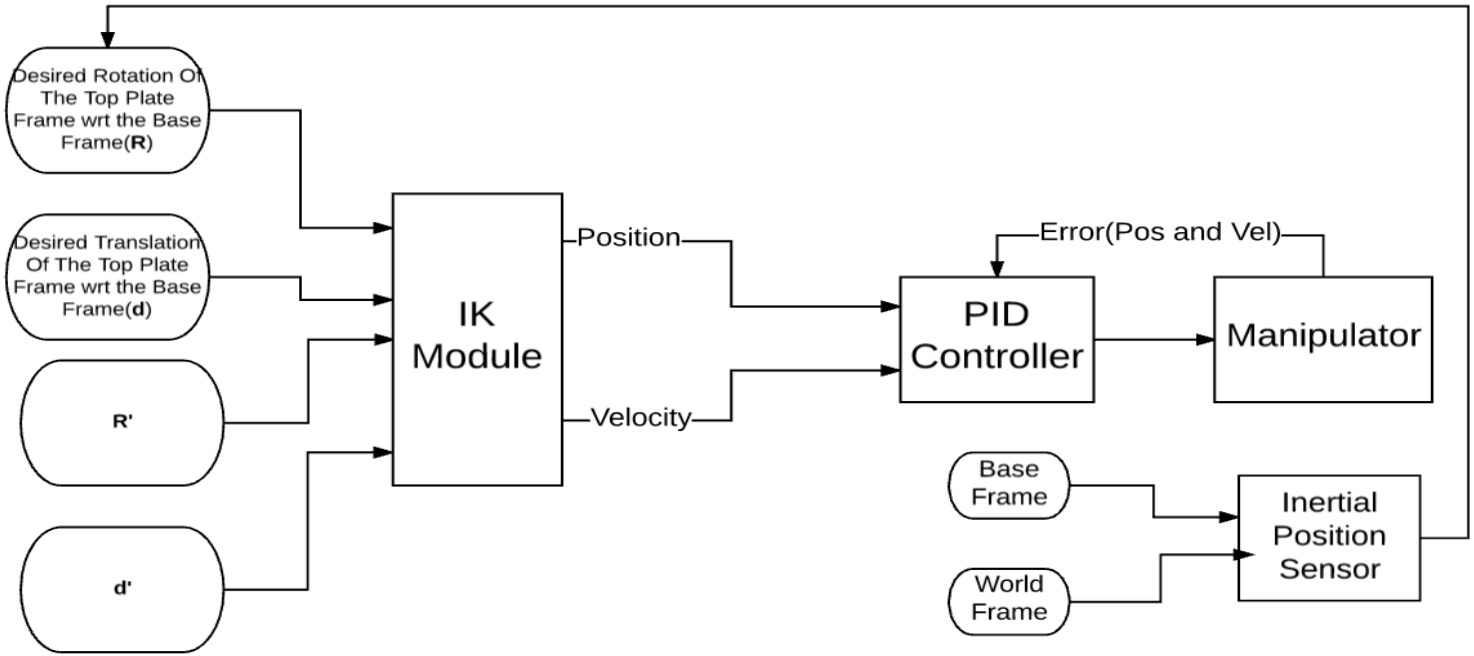
$$l_i = \mathbf{T} + {}^{P}\mathbf{R}_B \cdot p_i - b_i$$

Inverted Stewart Platform

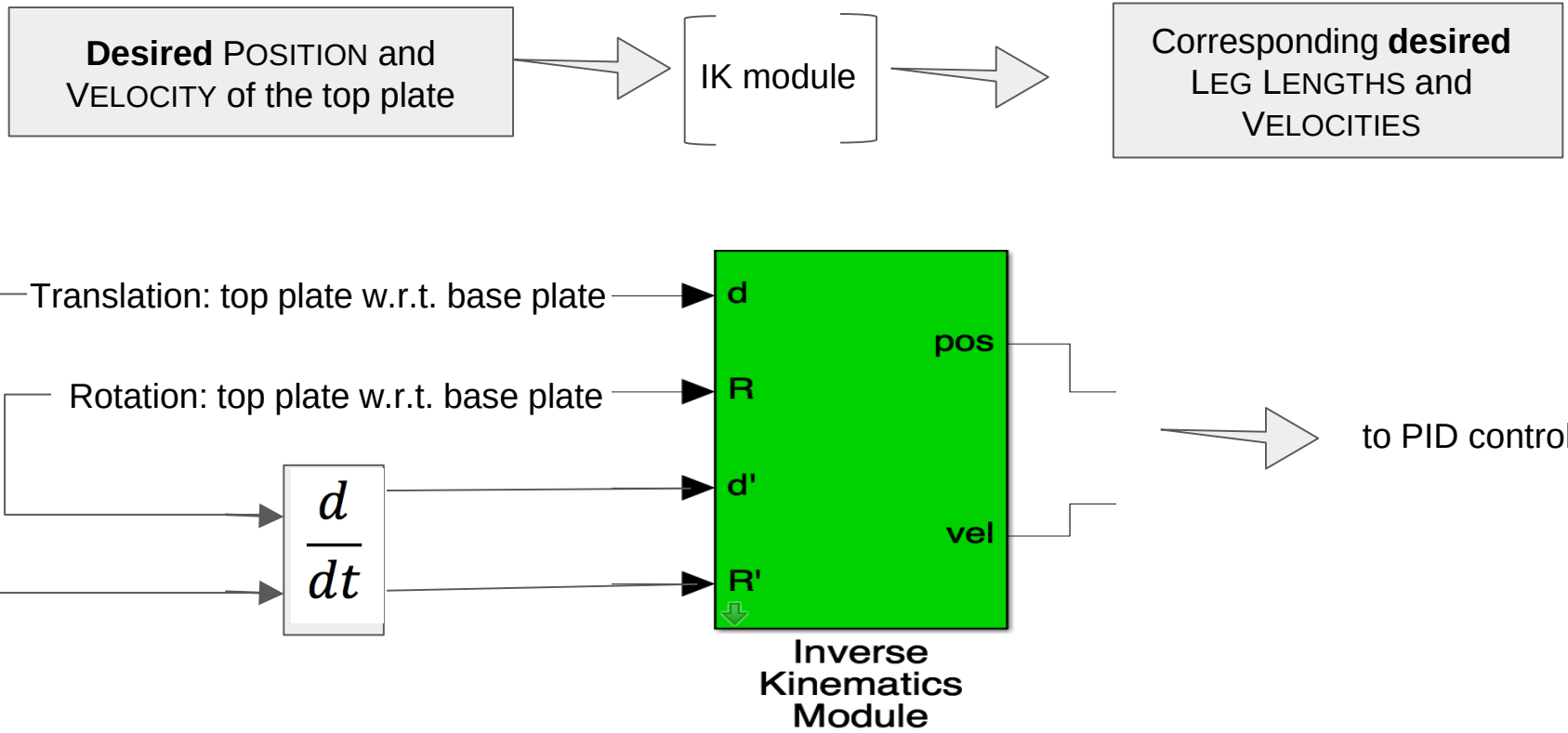


- Base Frame is in motion.
- IK is calculated using the moving Base Frame as reference.
- **Goal**- Frame attached to the Top Plate must follow the same orientation as the World Frame.

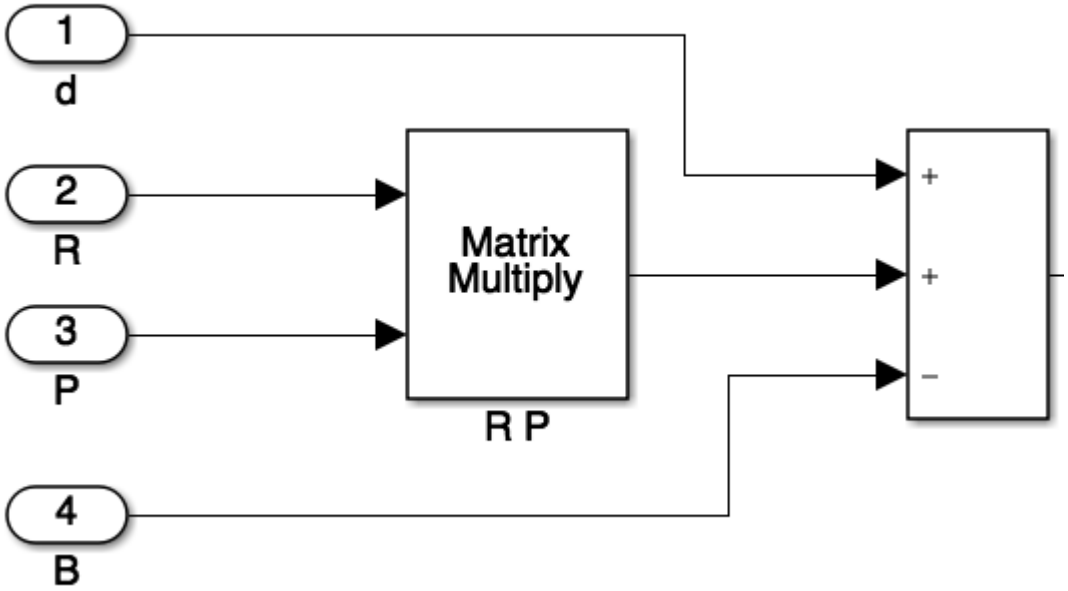
Block Diagram of the System



Inverse Kinematics block



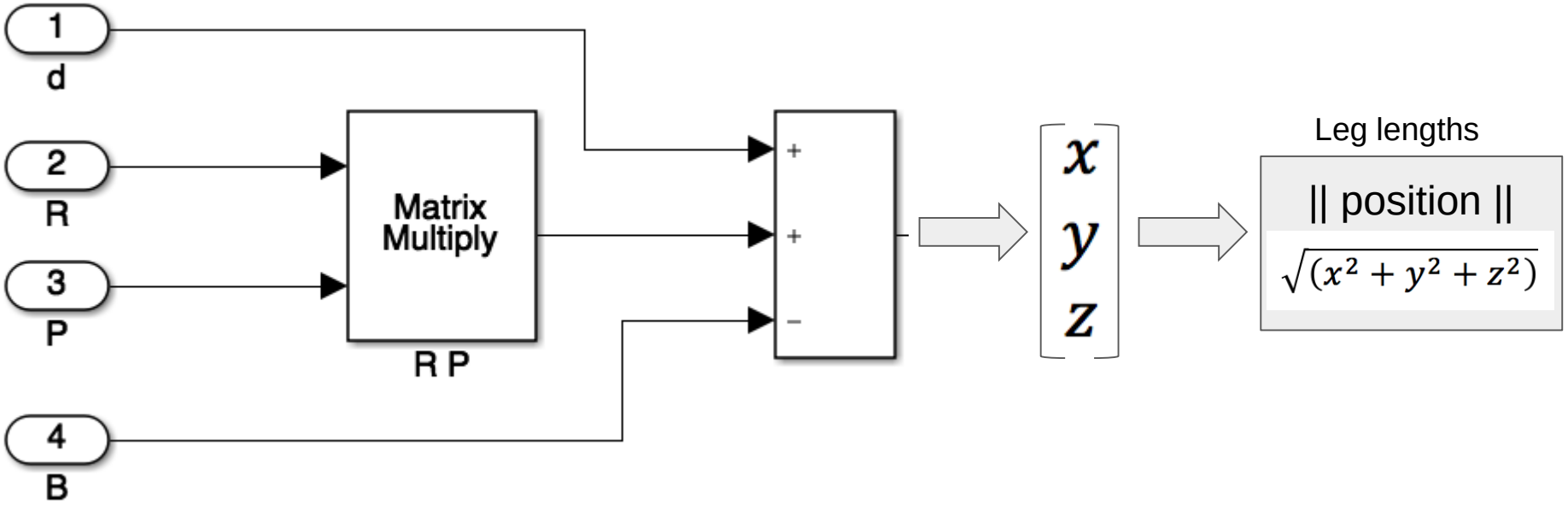
Inverse Kinematics - position computation



$$l_i = T + {}^{P}R_B \cdot p_i - b_i$$

p_i and b_i are fixed

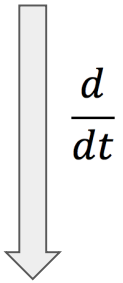
Inverse Kinematics - position computation



Inverse Kinematics - velocity computation

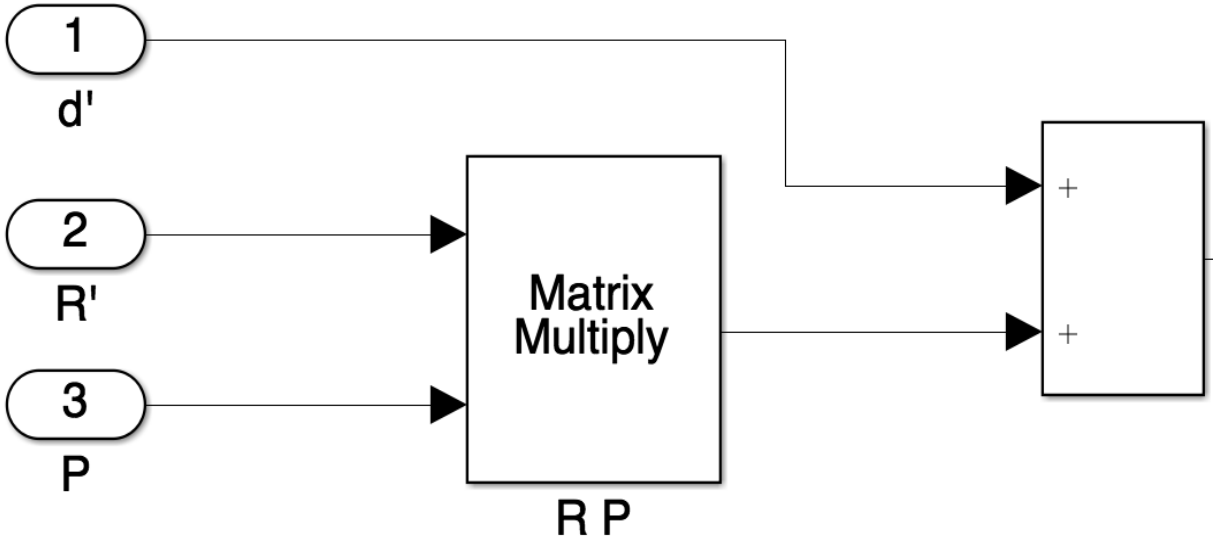
$$l_i = \mathbf{T} + {}^{P}\mathbf{R}_{B} \cdot p_i - b_i$$

p_i and b_i are fixed



$$v_i = \dot{T} + \dot{R} * p_i$$

Inverse Kinematics - velocity computation



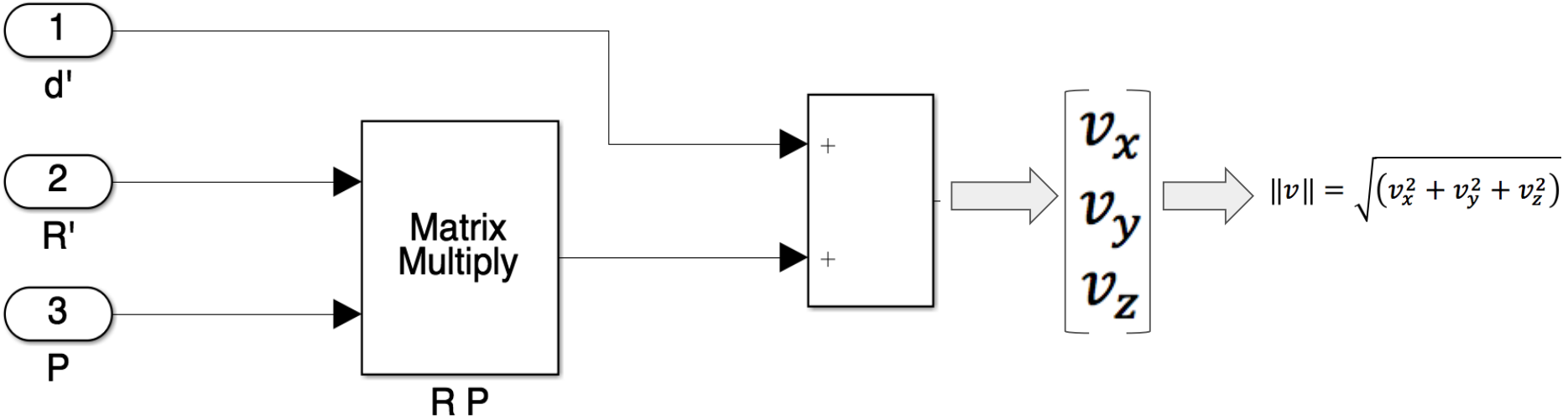
$$l_i = T + {}^{P}R_B \cdot p_i - b_i$$

p_i and b_i are fixed

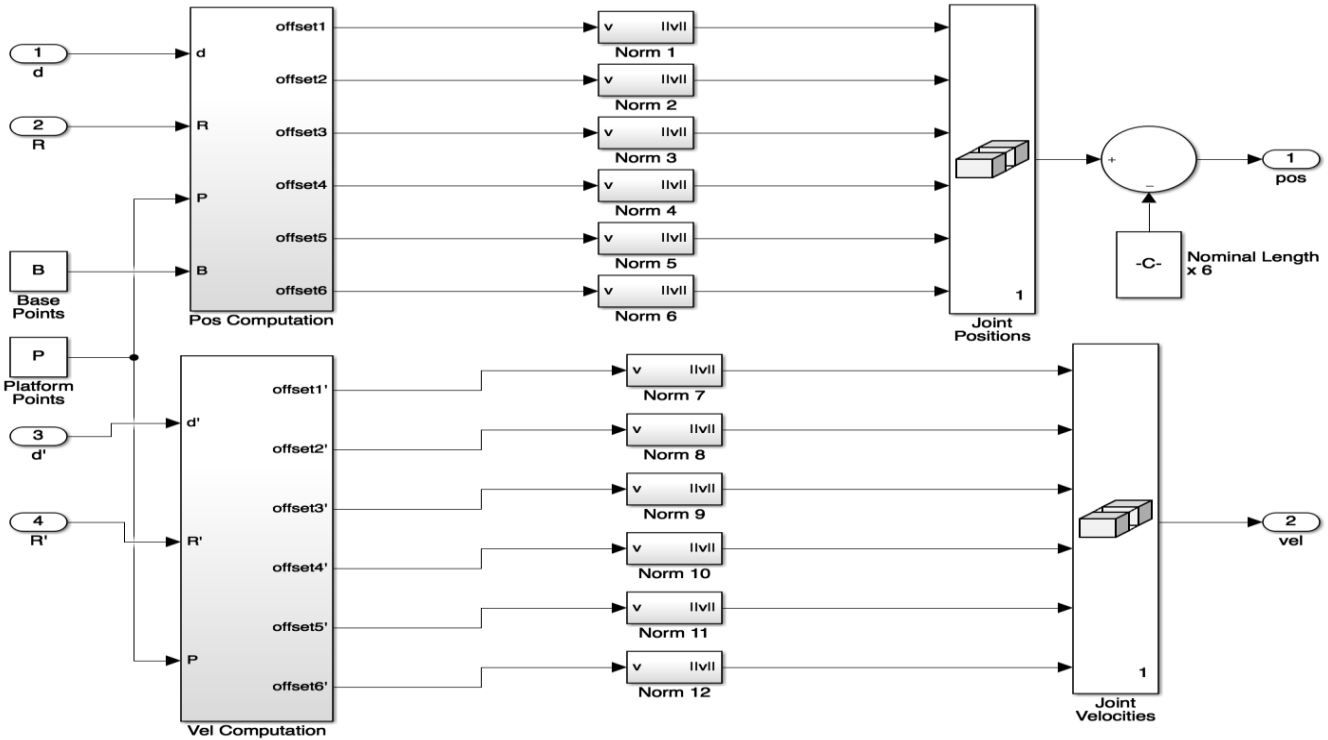
$$\frac{d}{dt}$$

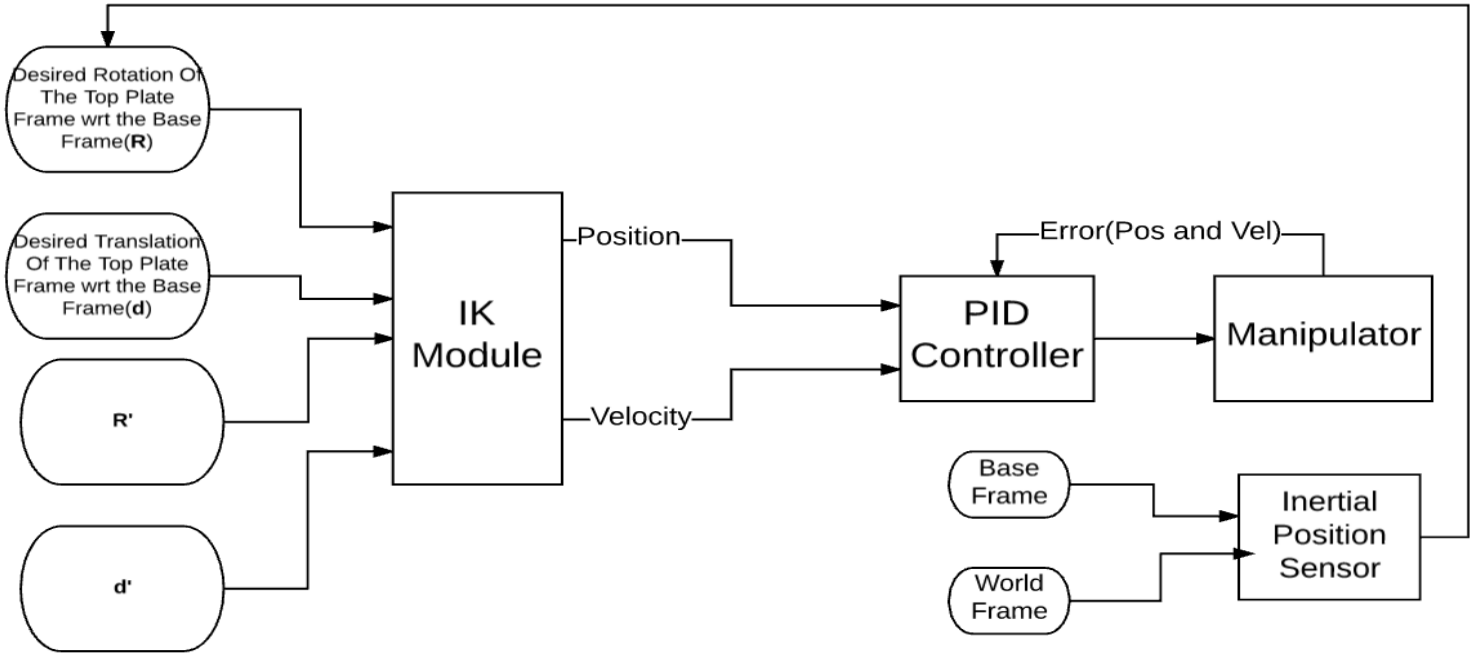
$$v_i = \dot{T} + \dot{R} * p_i$$

Inverse Kinematics - velocity computation



Inverse Kinematics




Desired Rotation Of The Top Plate Frame wrt the Base Frame(R)
Desired Translation Of The Top Plate Frame wrt the Base Frame(d)
R'
d'
IK Module
Position
Velocity
Error(Pos and Vel)
PID Controller
Manipulator
Base Frame
World Frame
Inertial Position Sensor

PID Control

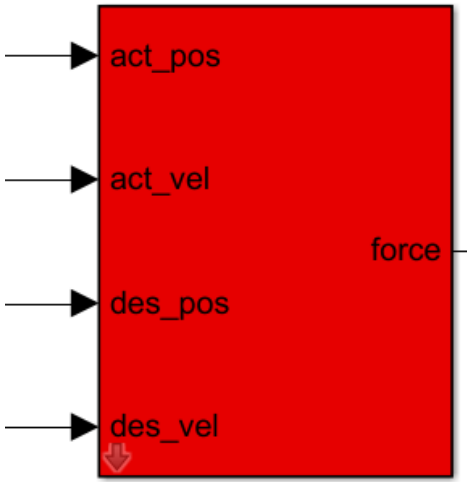
Actual and **Desired** POSITION and VELOCITY → **PID Controller** → **Desired** TORQUE for each Leg

Actual POS from Manipulator

Actual VEL from Manipulator

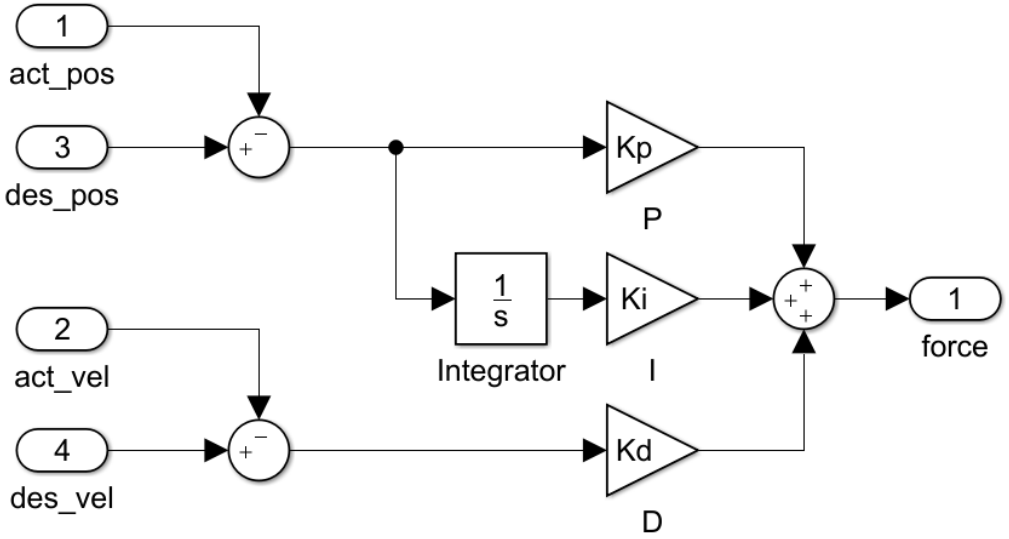
Desired POS from IK Block

Desired VEL from IK Block

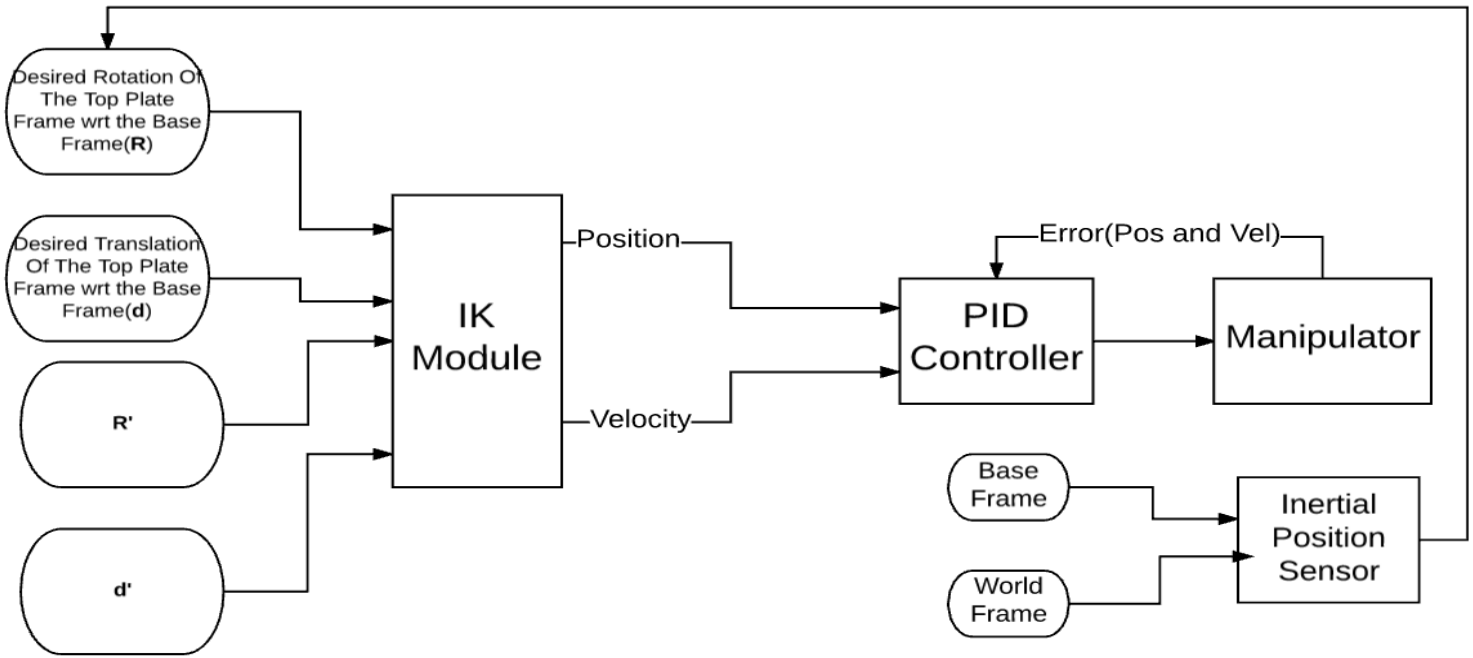


to Manipulator Block

PID Control



$$\boldsymbol{\tau} = K_p\tilde{\boldsymbol{q}} + K_v\dot{\tilde{\boldsymbol{q}}} + K_i\int_0^t \tilde{\boldsymbol{q}}(\sigma)\,d\sigma$$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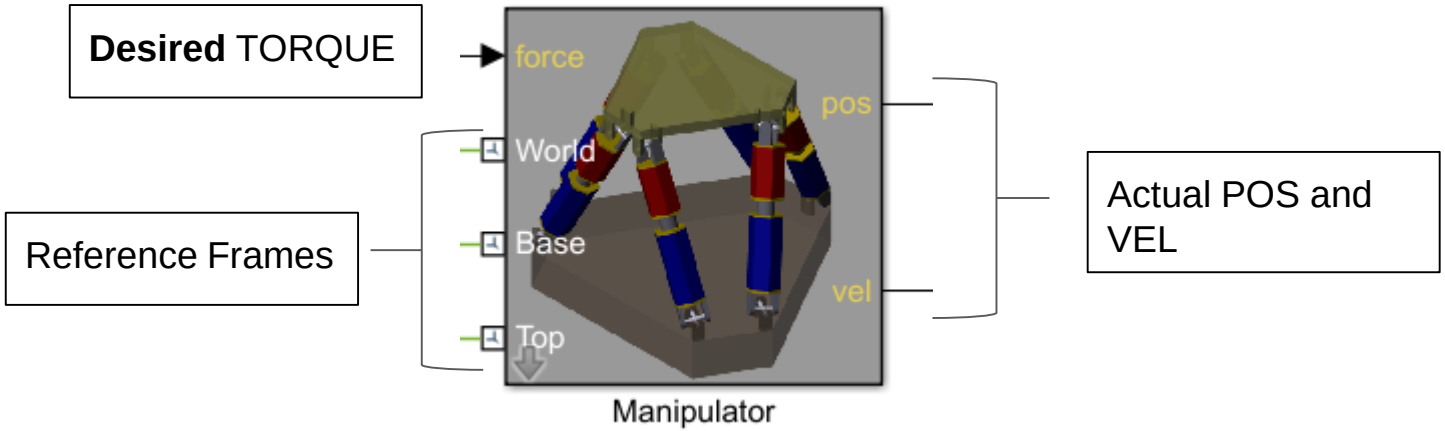
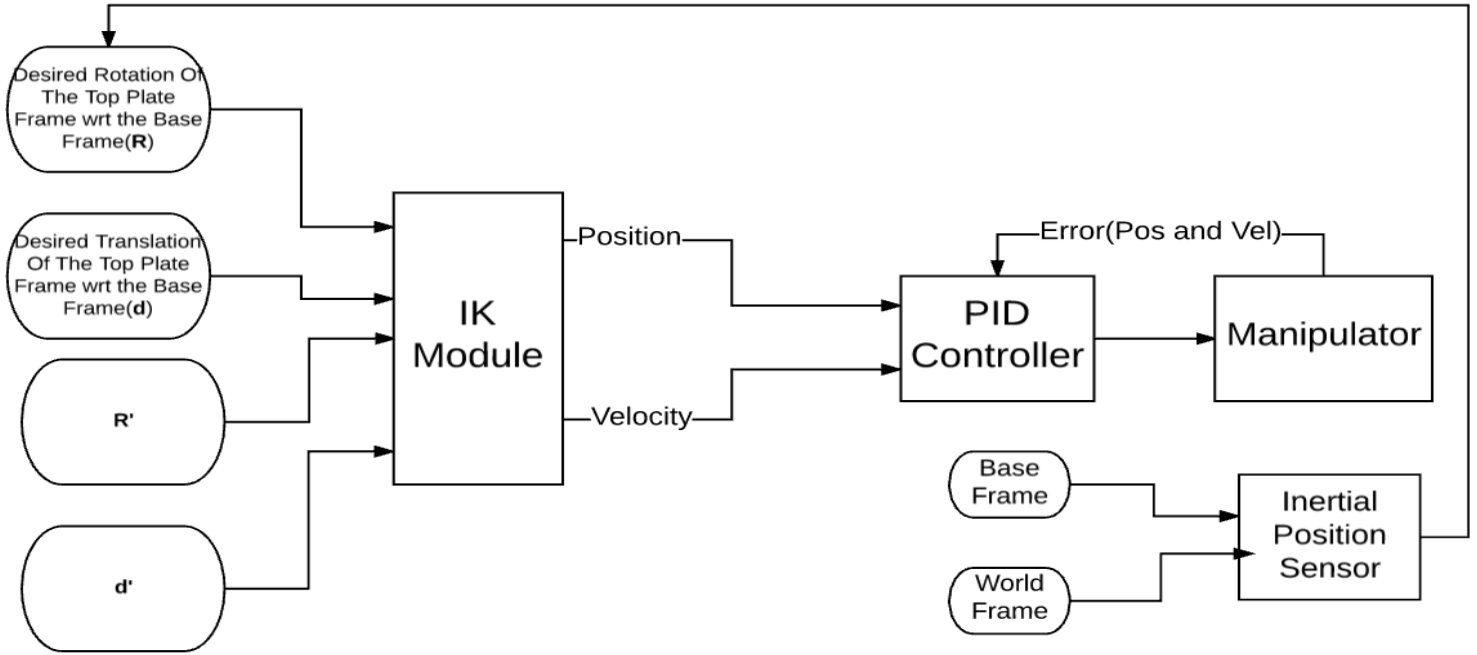
Manipulator Block

Desired TORQUE for each Leg → Manipulator → Actual POS and VEL for each Leg

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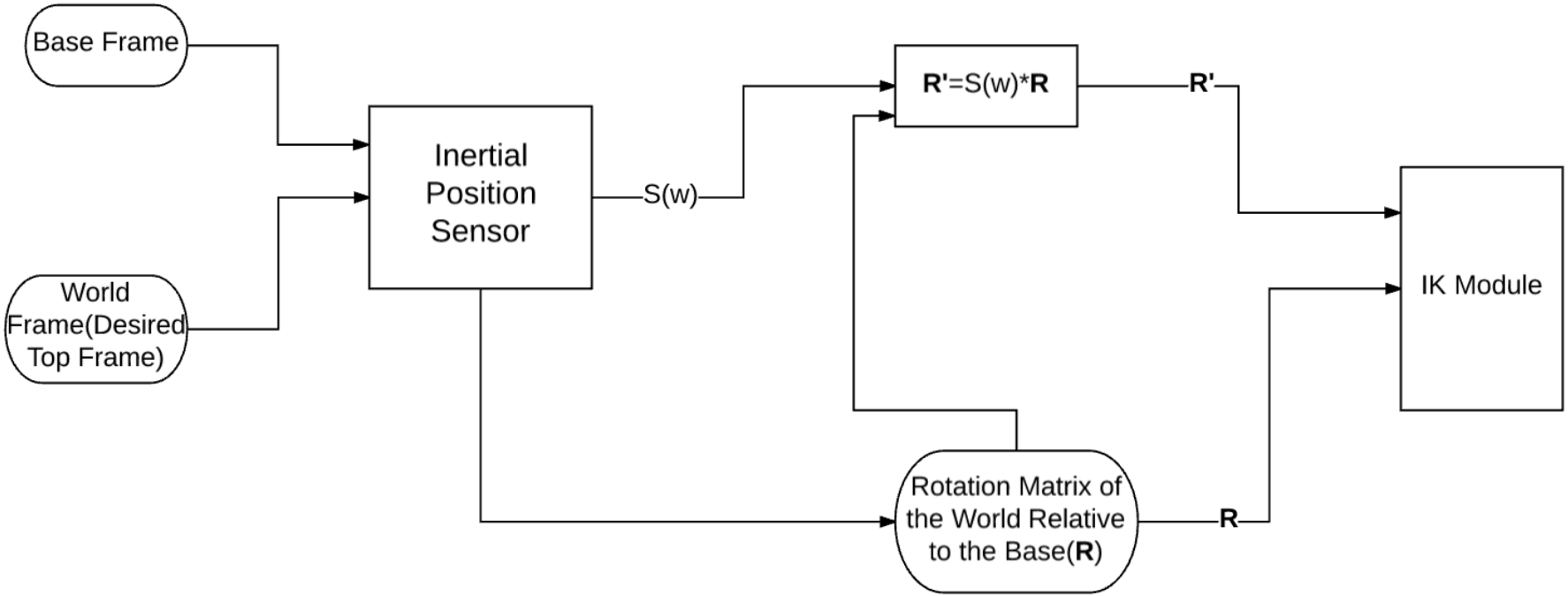
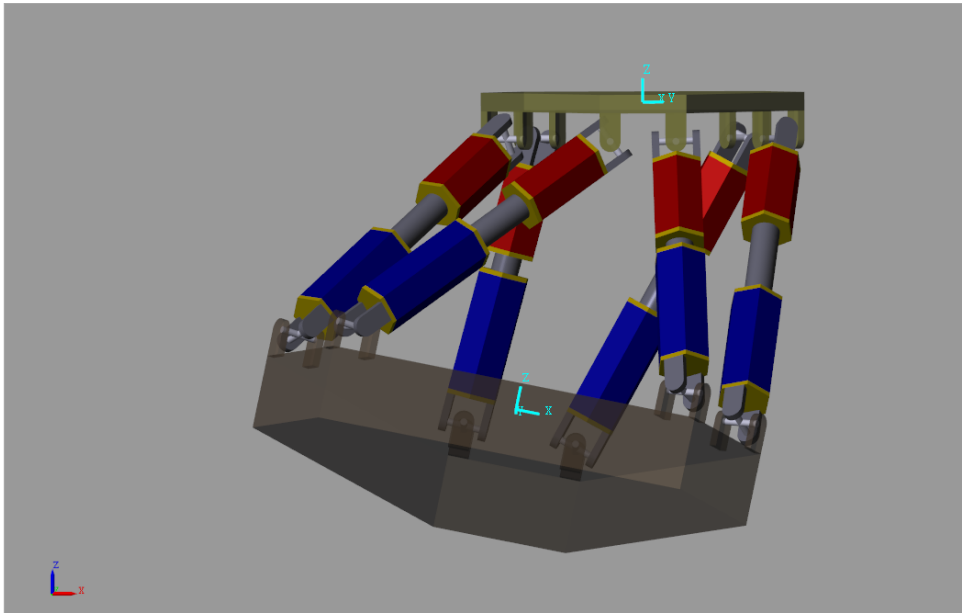
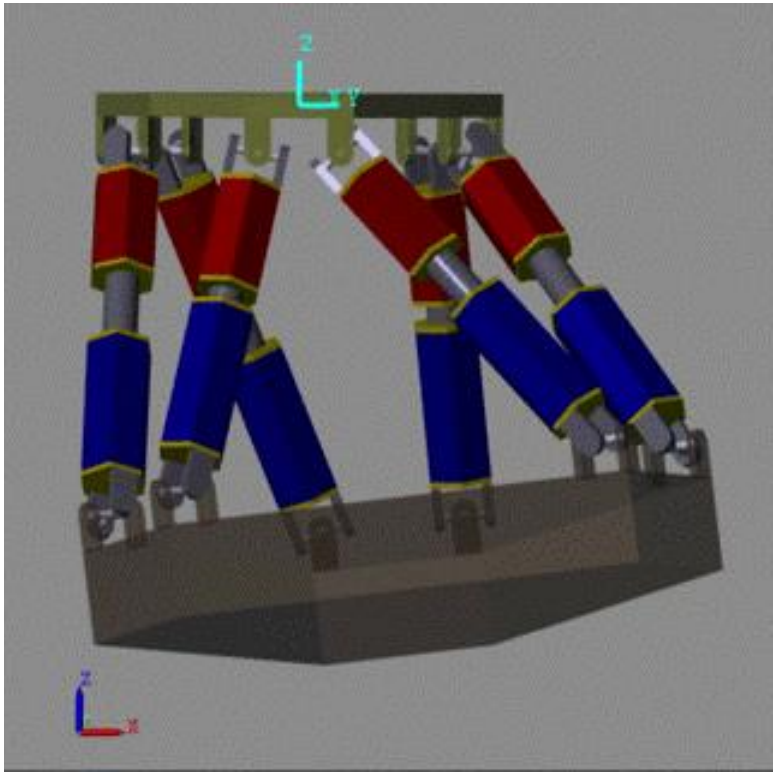


Desired Top Plate Orientation-> World Frame

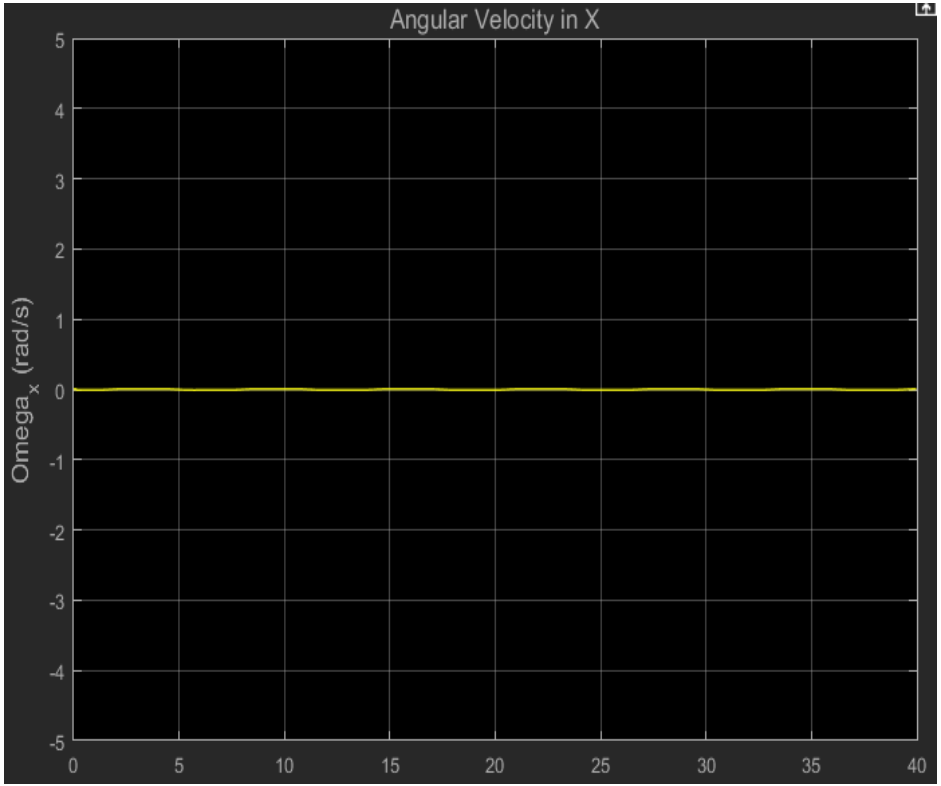


- Rotation Matrix from the World Frame to the Frame Attached to the Top Plate should be an Identity Matrix.
- IK must be calculated using the rotation matrix of the Top Plate relative to the Platform Base.

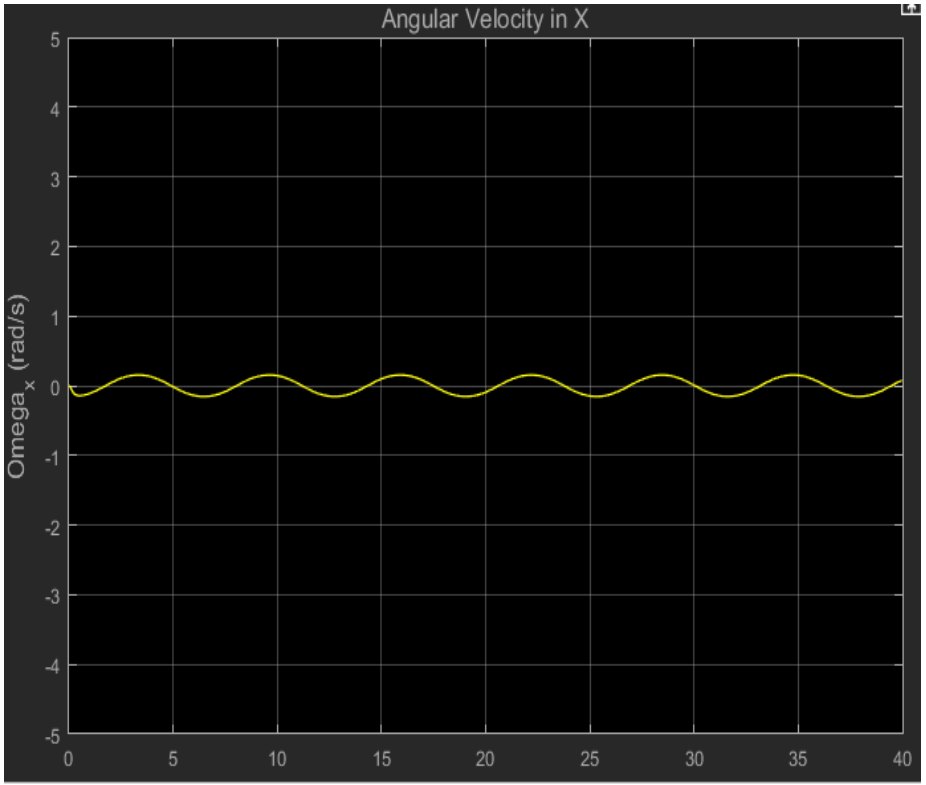
Animation of the Stewart Platform



Angular Velocities in X

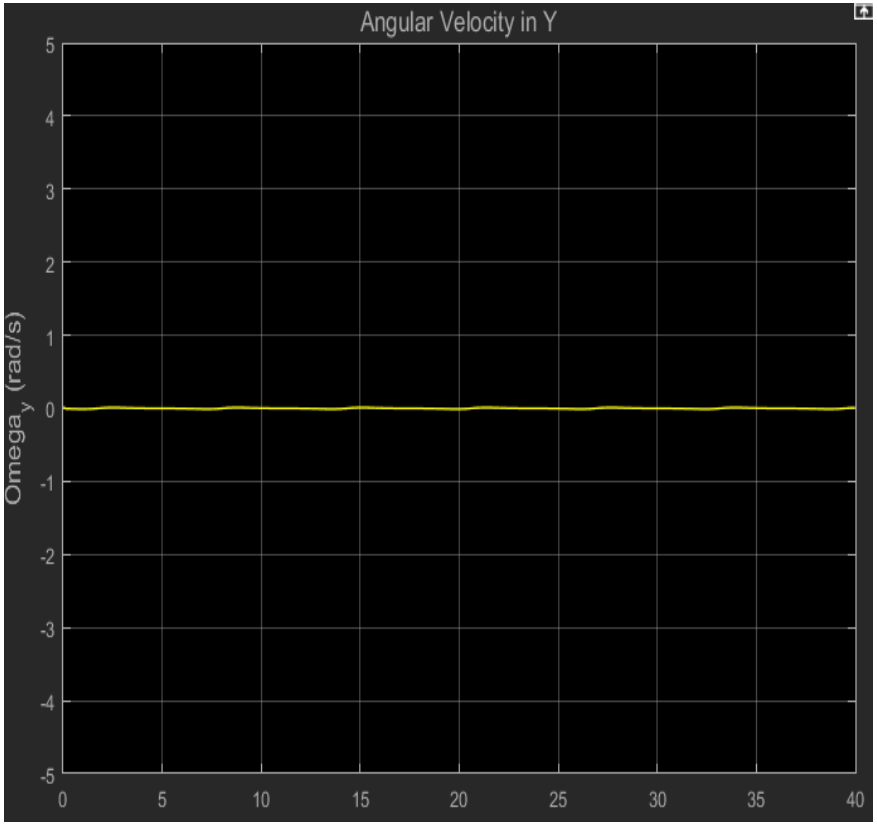


Wrt World Frame

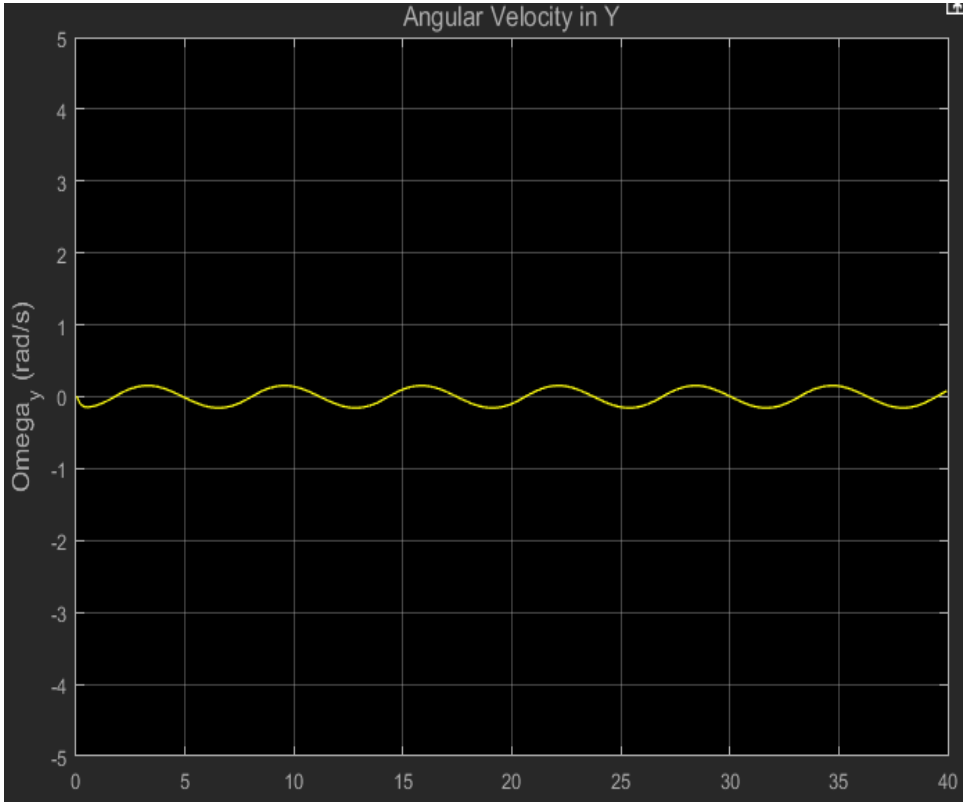


Wrt Base Frame

Angular Velocities in Y

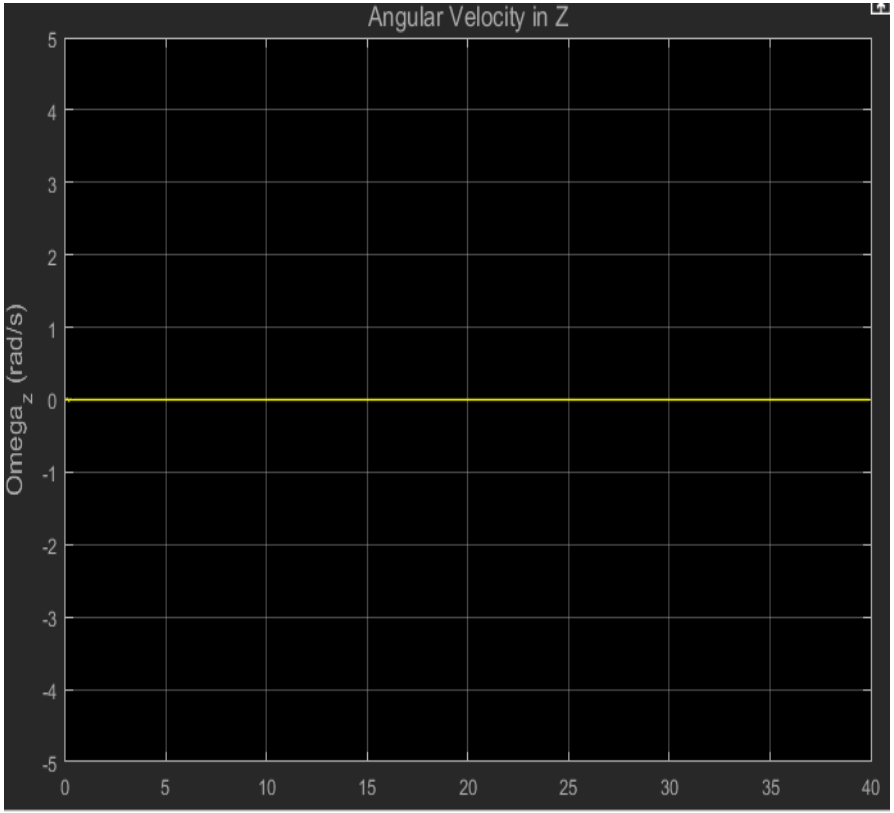


Wrt World Frame

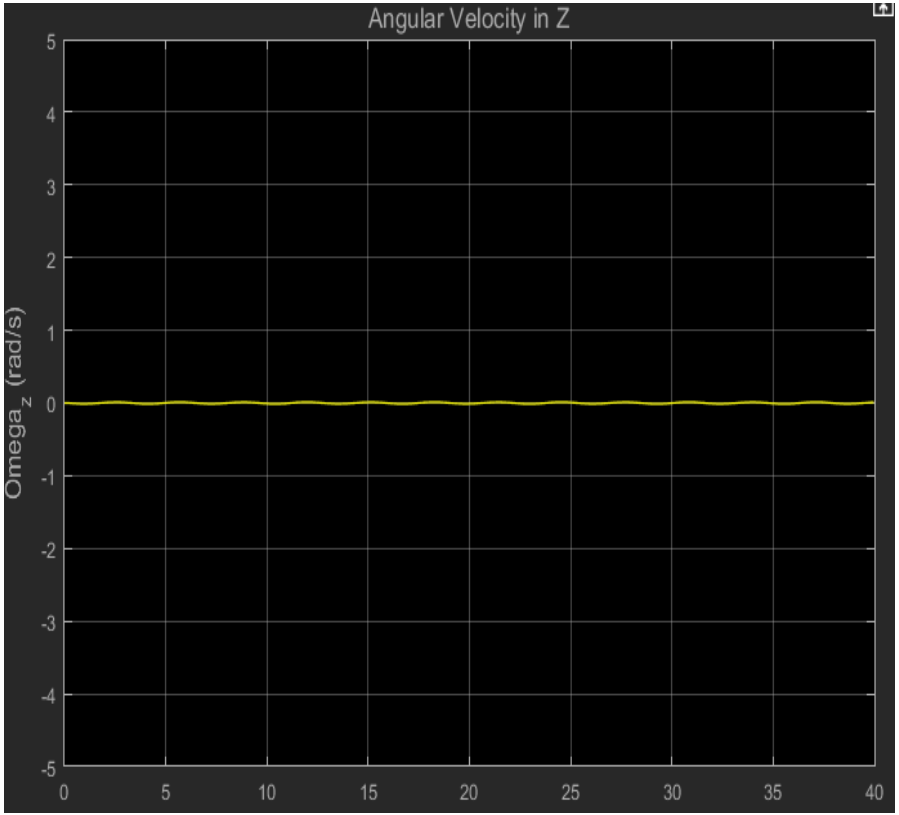


Wrt Base Frame

Angular Velocities in Z

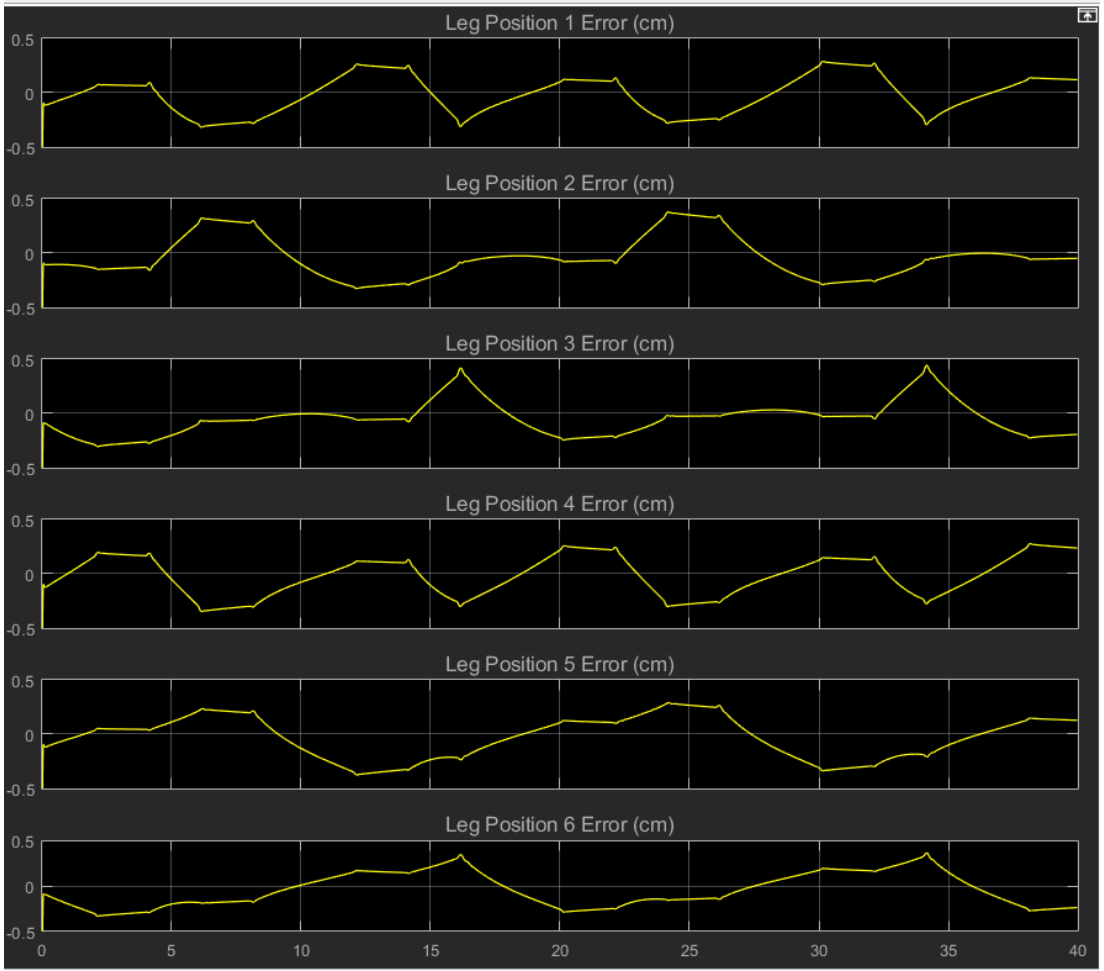


Wrt World Frame



Wrt Base Frame

Leg Position Errors



With more time ..

- Better verification: getting balls on to the top plate
- Simulating the physics: friction

Success criterion: no balls should get displaced due to disturbances