



## Task projection

### 1. Hip Task

Control in speed in X axis

$$\begin{aligned}
 x_{hip} &= l_1 \sin(q_1) \\
 z_{hip} &= l_1 \cos(q_1) \\
 J_{hip} &= \begin{bmatrix} l_1 \cos(q_1) & 0 & 0 \\ -l_1 \sin(q_1) & 0 & 0 \end{bmatrix} \\
 f_{hip} &= \begin{bmatrix} k dx_{hip}(v_{hipRef} - dx_{hip}) \\ 0 \end{bmatrix} \\
 u_{hip} &= B^+ J_{hip}' f_{hip}
 \end{aligned}$$

### 2. Top Task

Control with damp between Hip and top:

$$\begin{aligned}
 x_{top} &= l_1 \sin(q_1) + l_3 \sin(q_3) \\
 z_{top} &= l_1 \cos(q_1) + l_3 \cos(q_3) \\
 J_{top} &= \begin{bmatrix} l_1 \cos(q_1) & 0 & l_3 \cos(q_3) \\ -l_1 \sin(q_1) & 0 & -l_3 \sin(q_3) \end{bmatrix} \\
 f_{top} &= \begin{bmatrix} k p x_{top}(x_{hip} - x_{top}) \\ k d z_{top}(0 - dz_{top}) \end{bmatrix} \\
 u_{top} &= B^+ J_{top}' f_{top}
 \end{aligned}$$

### 3. Swing foot Task

Trajectory to follow:

$$z_{target} = h \sin\left(\frac{\pi}{stepLength}(x_{swf} - x_{0_{swf}})\right)$$

Control position for z and speed for x:

$$\begin{aligned}
 x_{swf} &= l_1 \sin(q_1) - l_2 \sin(q_2) \\
 z_{swf} &= l_1 \cos(q_1) - l_2 \cos(q_2)
 \end{aligned}$$

$$J_{swf} = \begin{bmatrix} l_1 \cos(q_1) & -l_2 \cos(q_2) & 0 \\ -l_1 \sin(q_1) & l_2 \sin(q_2) & 0 \end{bmatrix}$$

$$f_{top} = \begin{bmatrix} kdx_{swf}(v_{swfRef} - dx_{swf}) \\ kpz_{swf}(z_{target} - z_{swf}) \end{bmatrix}$$

$$u_{swf} = B^+ J_{swf}' f_{swf}$$

#### 4. Control total:

$$u = u_{hip} + u_{top} + u_{swf}$$

### Optimization choices

To choose the different parameters, we chose to make use of the Global Optimization Toolbox.

A MultiStart problem is created with 200 starting points, different lower bounds and upper bounds are chosen for the initial position, initial velocity,  $kdx_{hip}$ ,  $kpx_{top}$ ,  $kdz_{top}$ ,  $h$ ,  $steplength$ ,  $kdx_{swf}$  and  $kpz_{swf}$ .

The objective function puts a penalty ( $\sim +1000$ ) when the mean velocity of the hip is negative, when the CoT is negative and when the mean height of the hip is lower than 0.3

It rewards a mean height of the hip when higher than 0.35 and a reward is created for the distance traveled by the robot