UNIVERSITY
OF TRENTO

Department of Industrial Engineering

Optimization Based Robot Control

Homework 1

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A.Y. 2022-2023

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0. Introduction

To perform the polynomial interpolation of the reference trajectories for the TSID, we set initial and final velocities to zero for each step because the points of the reference trajectories are those where the feet both touch the floor. Furthermore, to find the four coefficients of the third-order polynomial, we need to make the starting and ending positions of the interpolating polynomials coincide with the reference points of each step (X_0 and X_1). The equations used for the computation are described in Equation 1.

$$\begin{cases} x(t) = a + b\,t + c\,t^2 + d\,t^3 \\ x(0) = X_0 \\ x(T) = X_1 \\ \dot{x}(0) = 0 \\ \dot{x}(T) = 0 \end{cases} \rightarrow \begin{cases} a = X_0 \\ b = 0 \\ c = -3\,\dfrac{X_0 - X_1}{T^2} \\ d = 2\,\dfrac{X_0 - X_1}{T^3} \end{cases}$$

Equation 1 - Third-order polynomial interpolation

The resulting polynomial interpolation is shown in Figure 1 (x axis), Figure 2 (y axis), Figure 3 (z axis). The first two steps are in place, while the other four allow us to analyze the robot during its walk.

1. Tuning of the weights

To fine-tune the main weights, in the beginning, we decide to give greater importance to the CoM to avoid unbalances of the robot (see Figure 4), especially in the initial stabilization. Then we realize that the robot had a problem in the last part of the walk caused by a too-low weight for the feet (Figure 5), which almost penetrated the floor, causing the robot to fall. Then, we decide to perform a trial-and-error tuning for proper tracking of the reference trajectories. The weight of the posture is not as important as the others. An excessive increase causes the robot to move by translating rather than walking. The final weights chosen are $w_{com} = 30, w_{foot} = 40, w_{posture} = 3$ (Figure 6, Figure 7, Figure 8).

2. Squat mode active

As suggested in the assignment, we started the squat simulation using the weights of point 1. The z coordinate of the CoM is shifted compared to the first case, but it is too far from the reference trajectory for the squat mode (non-optimal weights and gain compared to the tuned one: Figure 9). The difference between the tuning of the weight w_{squat} (Figure 10) and the tuning of the proportional gain Kp_{squat} (Figure 11) is that with the proportional gain approach the trajectories and the velocities start closer but oscillate more compared to the weight approach.

3. Push mode active

With the weights chosen in the first point, the robot does not fall. With the push mode active, there is an increment in the proportional gain for the CoM of ten times. In this case, with standard settings, the CoM has higher relative importance compared to the foot one. Hence, to compensate for this effect, it is necessary to increase the weight of the foot.

4. Squat and Push mode active

With both push and squat active, we performed two different simulations. The second one has a very high proportional gain for the squat, which causes oscillations responsible for the robot's fall. The first simulation, with a higher weight and a lower proportional gain for the squat, allows the robot to complete the task due to the lower oscillation and a smoother transition (Figure 12). To allow the second simulation to work, we have increased the CoM, foot and posture weights.

5. Plots

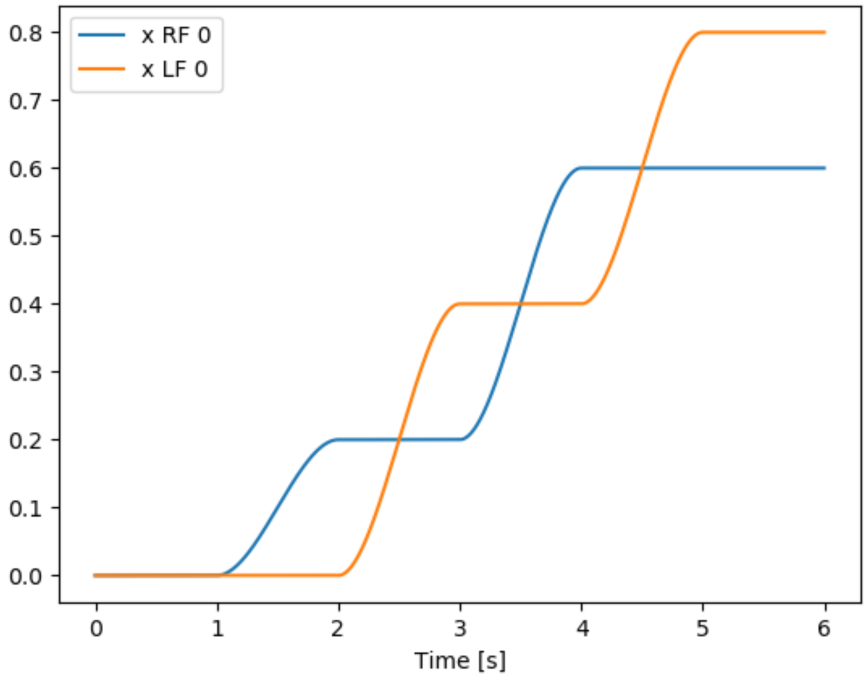

Figure 1 – x trajectories of right and left foot

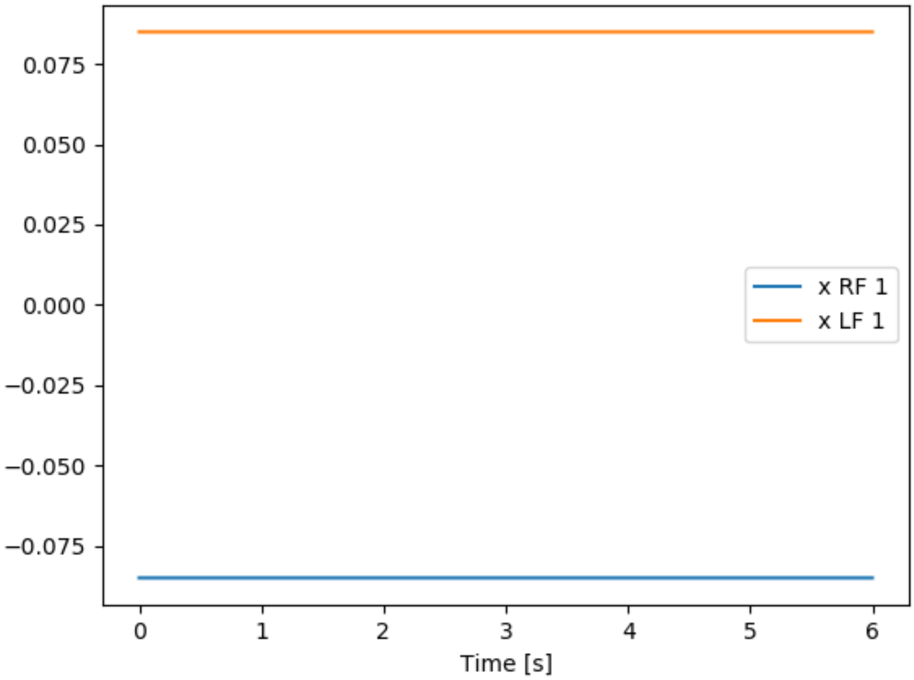

Figure 2 – y trajectories for right and left foot

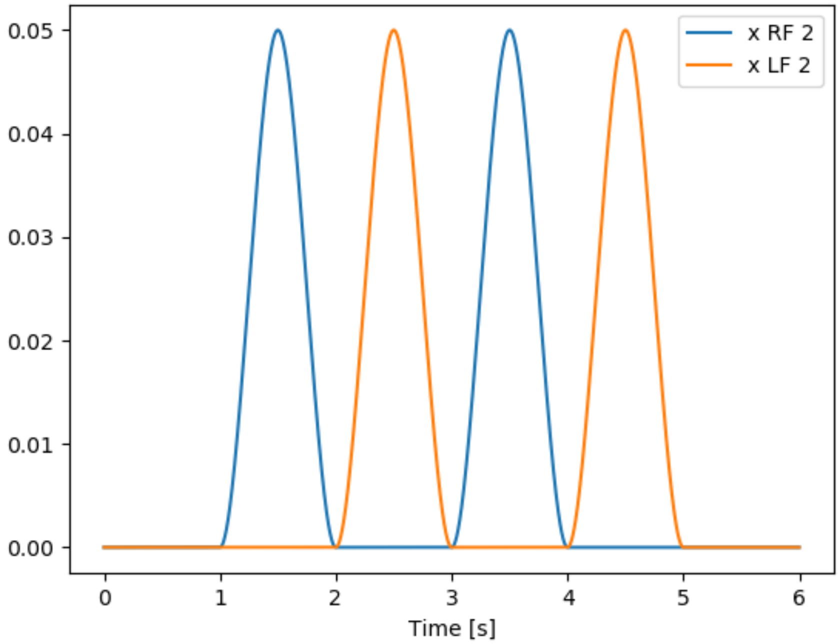

Figure 3 – z trajectories for right and left foot

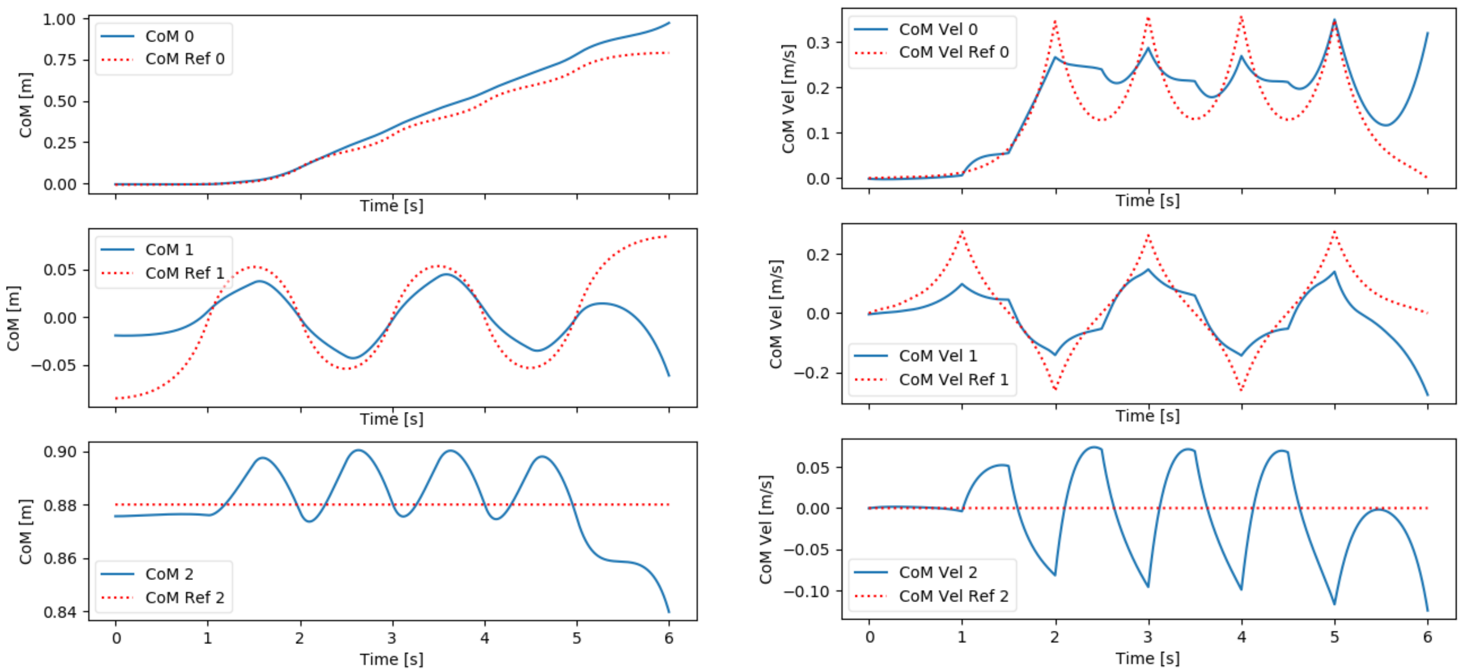

Figure 4 - Position and velocity of the CoM with a low CoM weight

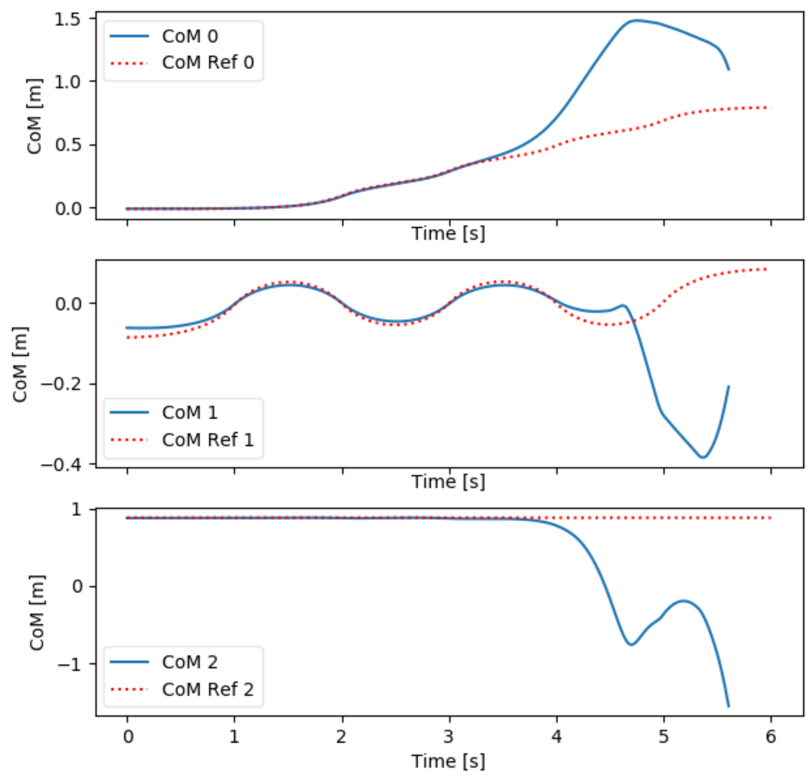

Figure 5 - CoM trajectory with a low foot weight

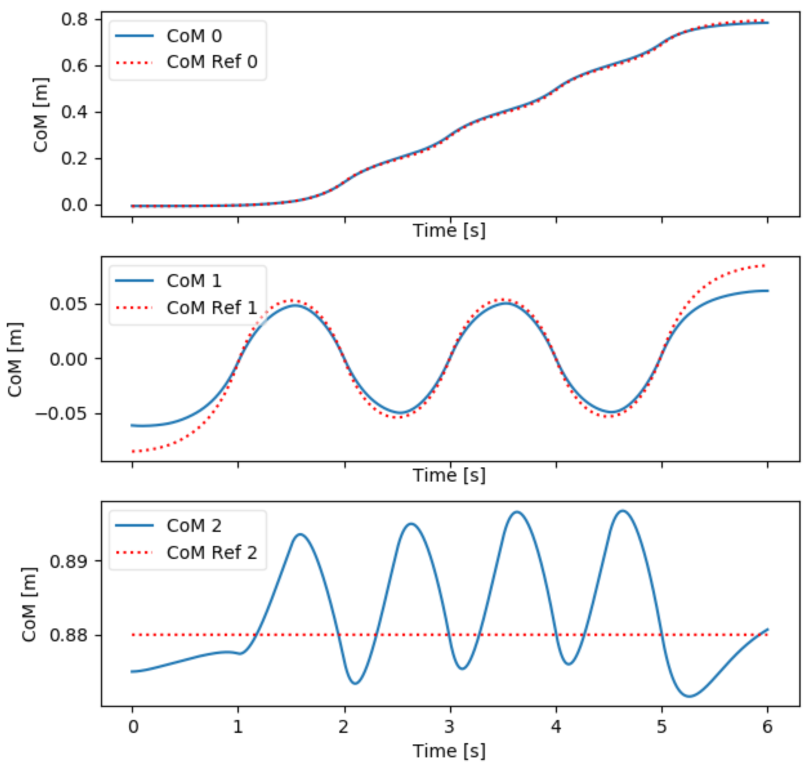

Figure 6 - CoM trajectories tuning CoM, posture and feet weights

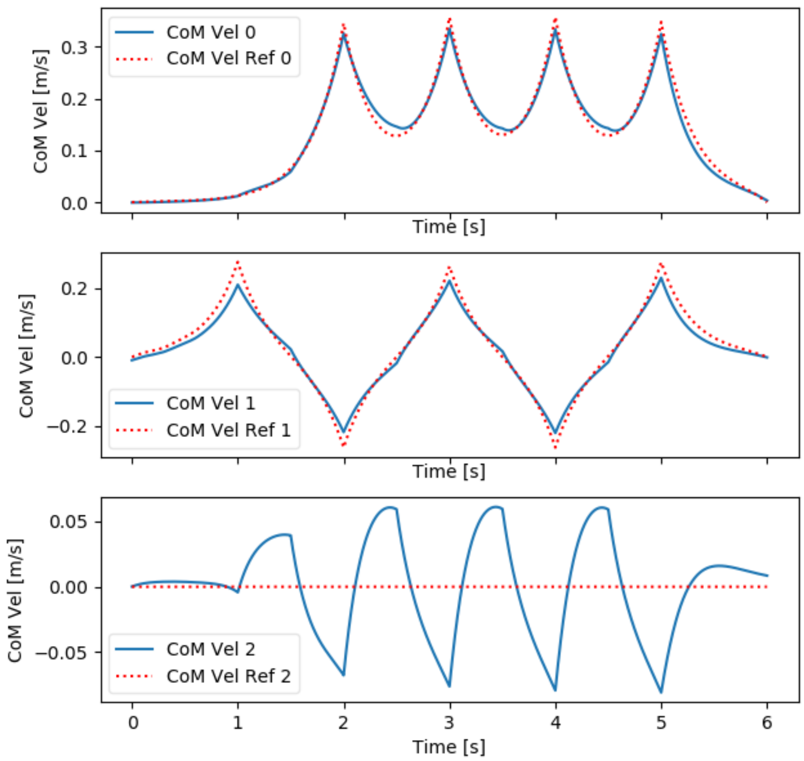

Figure 7 - CoM velocities tuning CoM, posture and feet weights

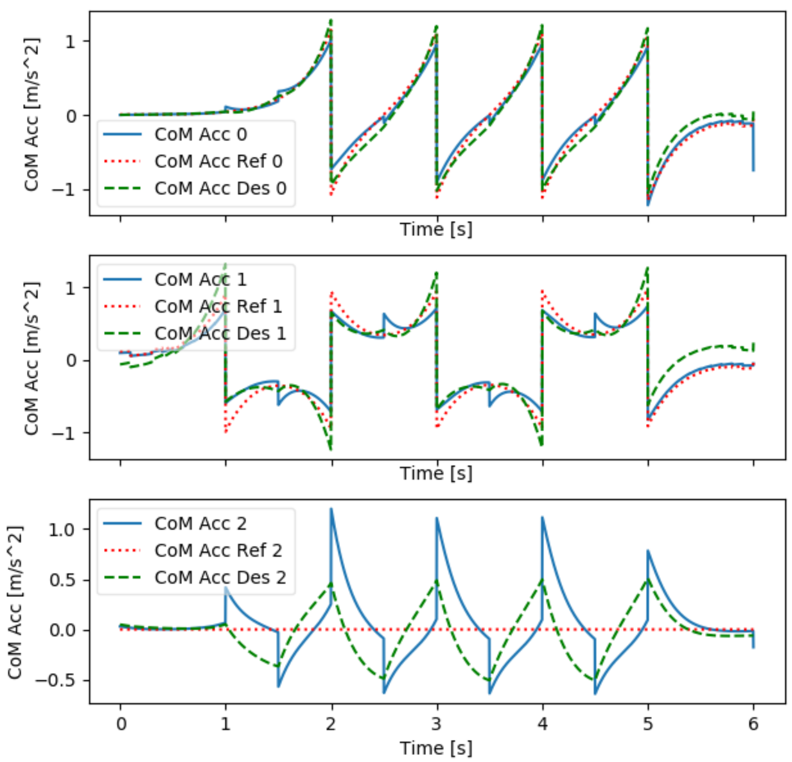

Figure 8 - CoM accelerations tuning CoM, posture and feet weights

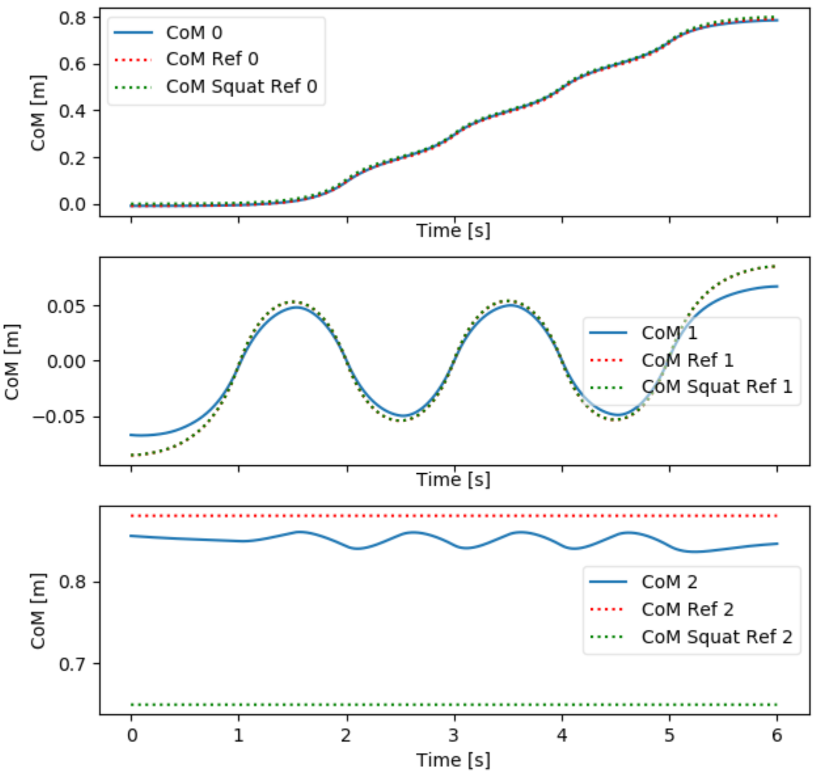

Figure 9 - Squat simulation with point 1 weights

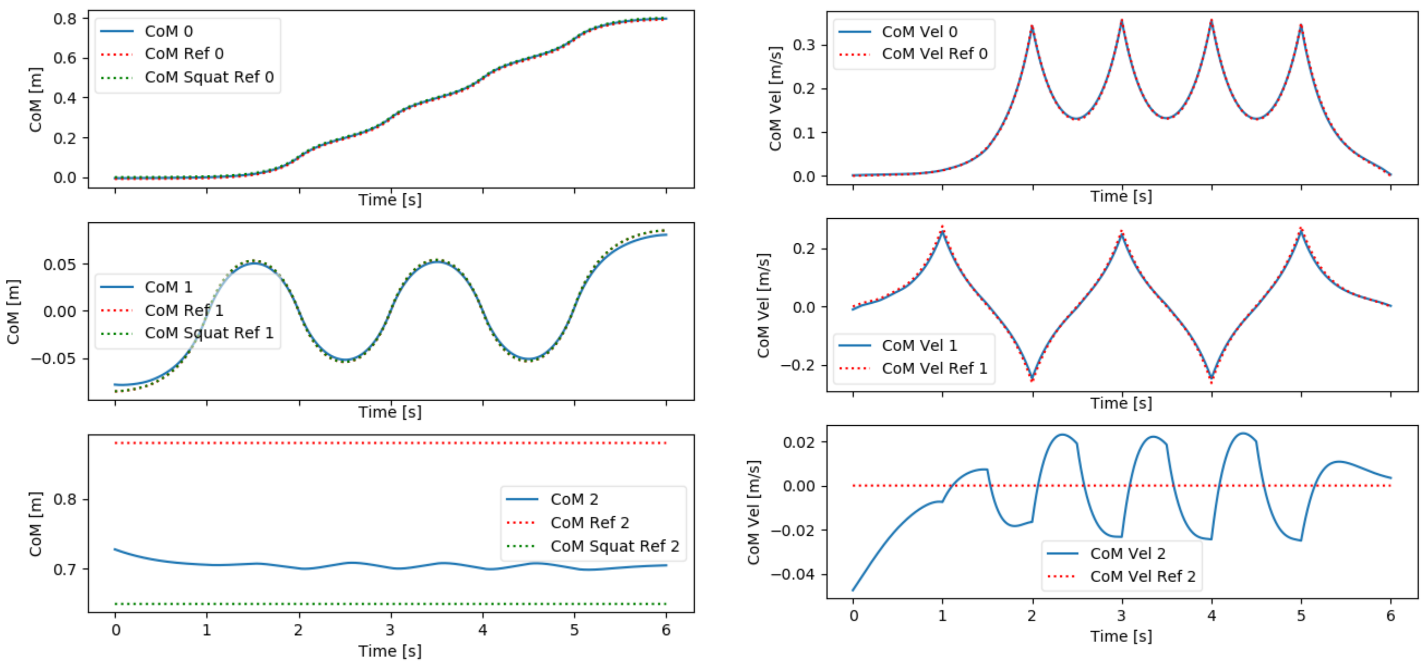

Figure 10 - Squat simulation with w_{squat} increased

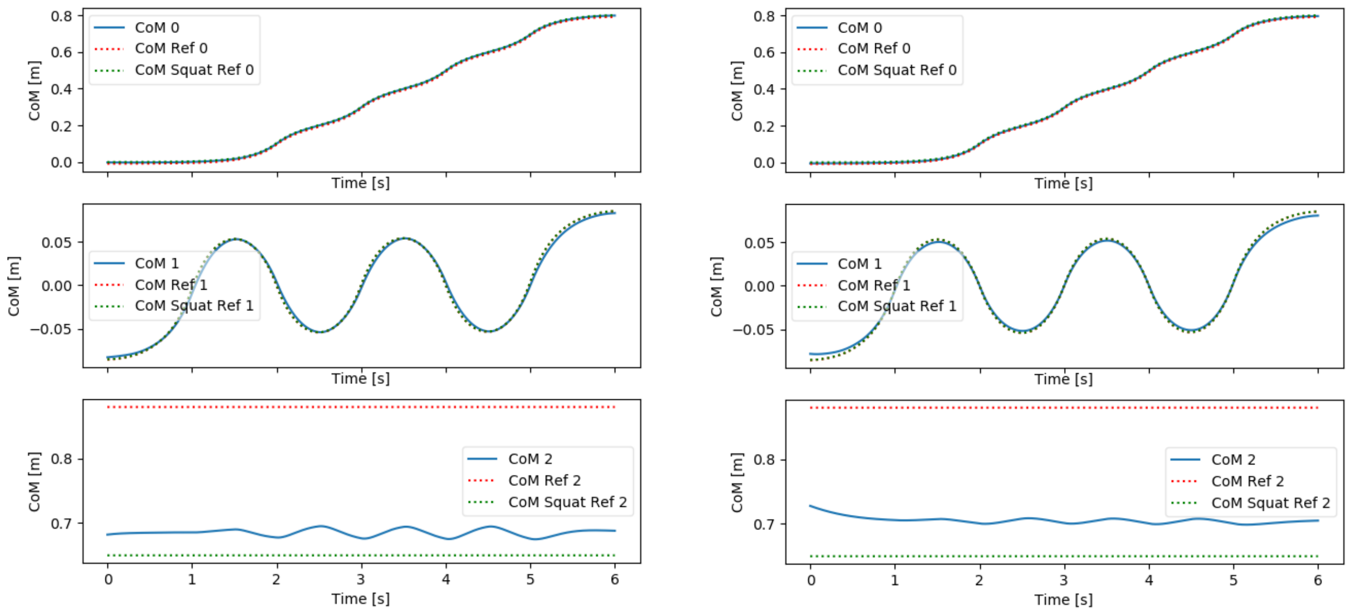

Figure 11 - Squat simulation with kp_{squat} increased

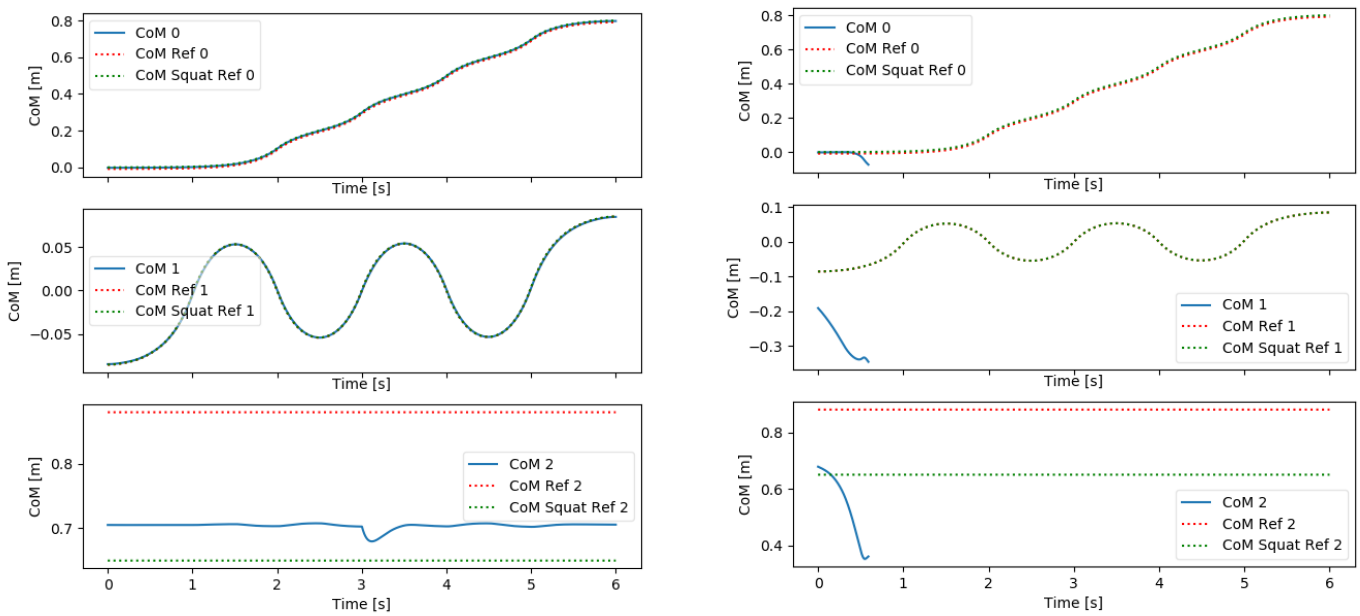

Figure 12 - Squat and push simulation in the two simulations