OPTIMIZATION BASED ROBOT CONTROL
FIRST ASSIGNMENT

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Note:

As suggested, in the implementation of the IC control law we used:
- K = 8*Kp
- B = 8*Kd.

Answers:

1. At low frequency, by looking at the results it is clear that IKID has the best average tracking error, followed by OSC, and IC. At high frequency, for Kp=50 the best one is still IKID with results close to IC, but when increasing Kp=100 only IC achieves to follow the trajectory and increases in performance, IKID and OSC become unstable resulting in no solution by the simulator.
See *figure 1*.

2. Randomizing the model of the robot, by looking at the results it can be seen that at every frequency and every Kp IC is always stable and has better performance with higher Kp. At low frequency, IKID is stable and gets better with higher Kp, but at high frequency, it becomes unstable or gets poor results in a few cases (just 1/2 out of 5 depending on Kp). OSC was stable 4 times over 5 at low frequency with Kp=50 and stable 2 times over 5 with Kp=100, at high frequency was stable only 1 time over 5 with both Kp=50 and Kp=100 with poor results.
See *figure 2.*

3. The robot makes some abrupt moves because there is not a postural task to stabilize the joints. By adding the postural task the robot is encouraged to have small joint velocities without affecting the end-effector position, so the robot tries to achieve the reference trajectory with the smallest movements of the joints.

4. By adding the postural task the average tracking error reduces significantly. At low frequency and Kp=50 the mean of the tracking errors for the methods is 0.032m, with Kp=100 the mean of the tracking errors is 0.021m, OSC and IKID perform similarly and slightly better than IC.
IC is the best at high frequency with Kp=50. With Kp=100 the performance was better on IKID and OSC than on IC.

Using the model randomization, on average, the three methods perform similarly at low frequency, IC performs a bit worse with respect to the other two. At the high frequency and Kp=50 OSC, IKID and IC show similar performance, but IC performs slightly better. With Kp=100 the best one seems to be IKID with values close to OSC. IC is the worst performing with this configuration.
See *figure 3* and *figure 4.*

5. Since real robots are difficult to be modeled, probably the most accurate and safer solution is IC since it always finds a solution and reliability is a very important factor in real-world robotic applications. Moreover, with IC it is possible to control also the operational-space inertia with a more complex control law and this extends the range of possible applications.
The drawback is that on average it performs slightly worse with respect to the other two methods in terms of mean tracking error. This can be addressed by tuning the gains better and complicating the control law. It is also very important to add the postural task, this results in lower joint acceleration, velocities, and torques hence the robot is easier to control and can perform the task in a better way.

Figures:

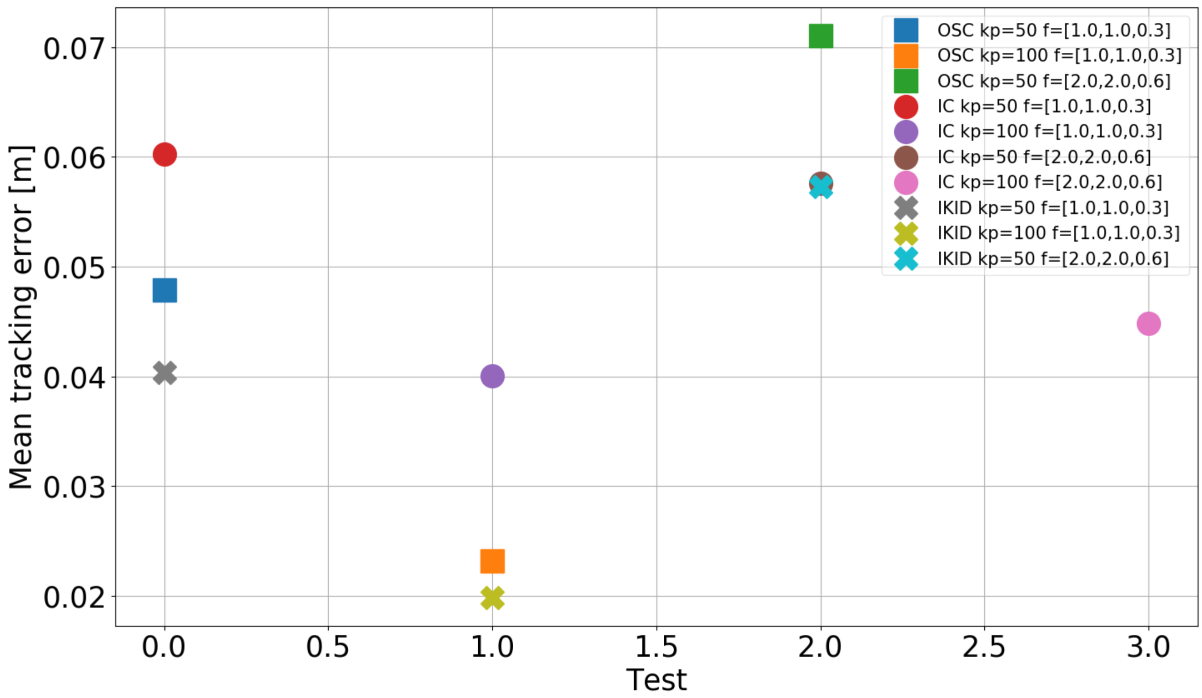

Figure 1: Results with standard robot model without postural task.

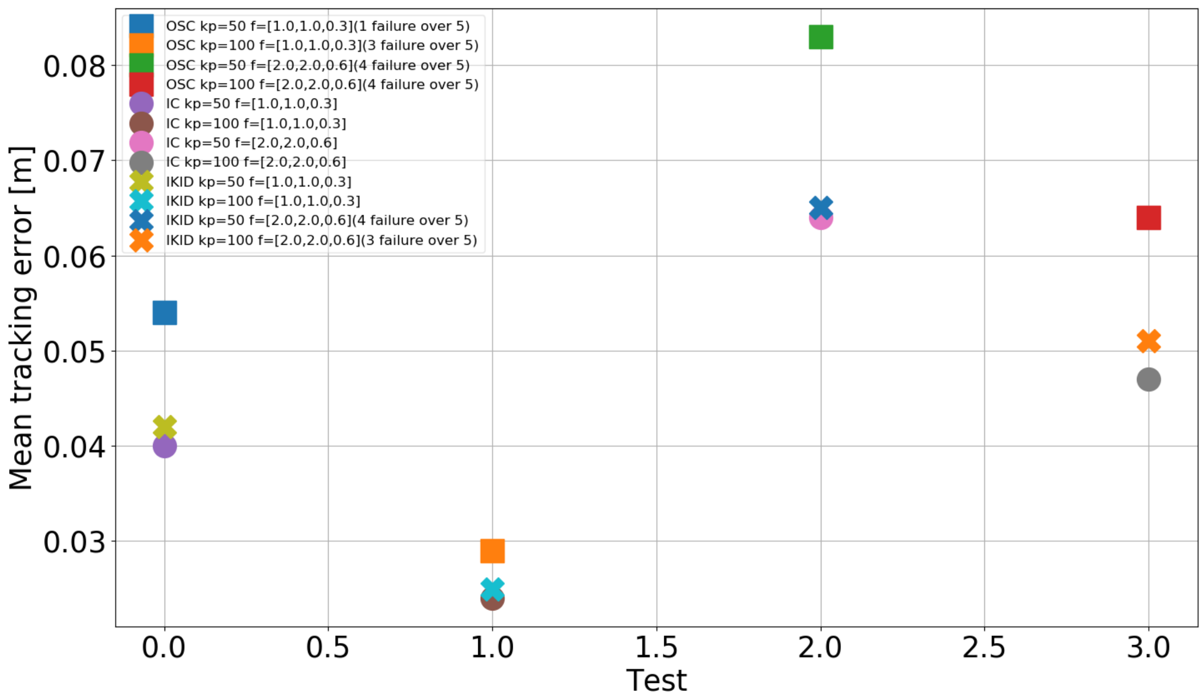

Figure 2: Results with random robot model without postural task.
The results are the average of 5 different simulations.

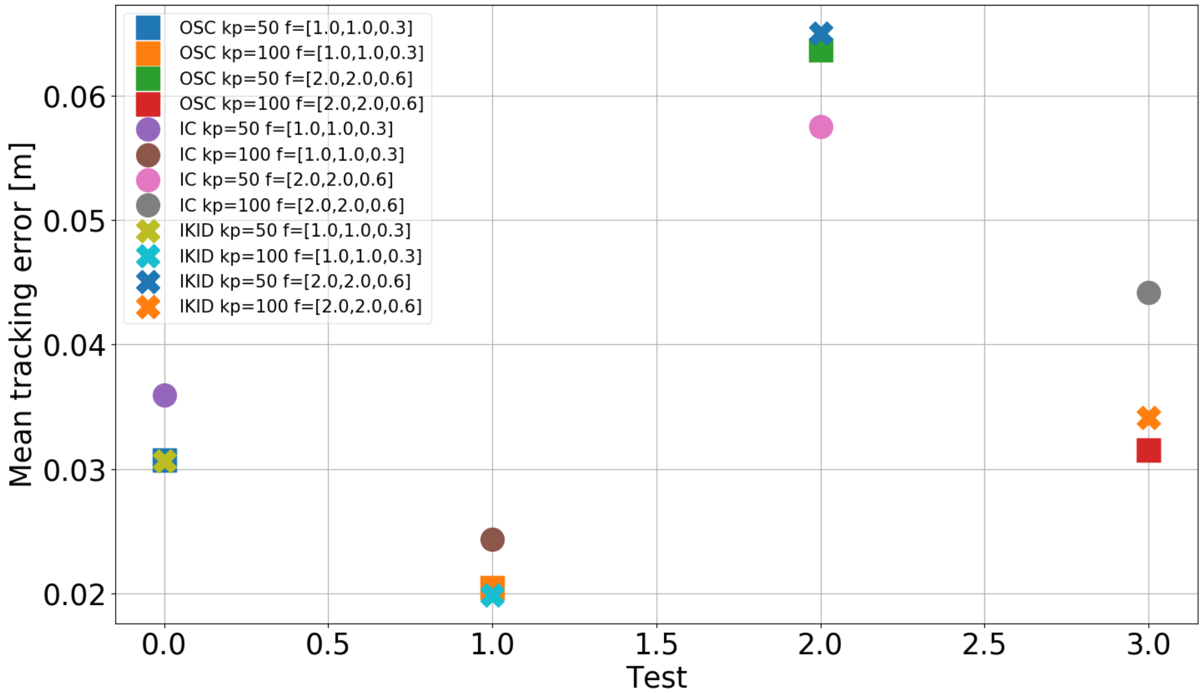

Figure 3: Results with standard robot model and postural task.

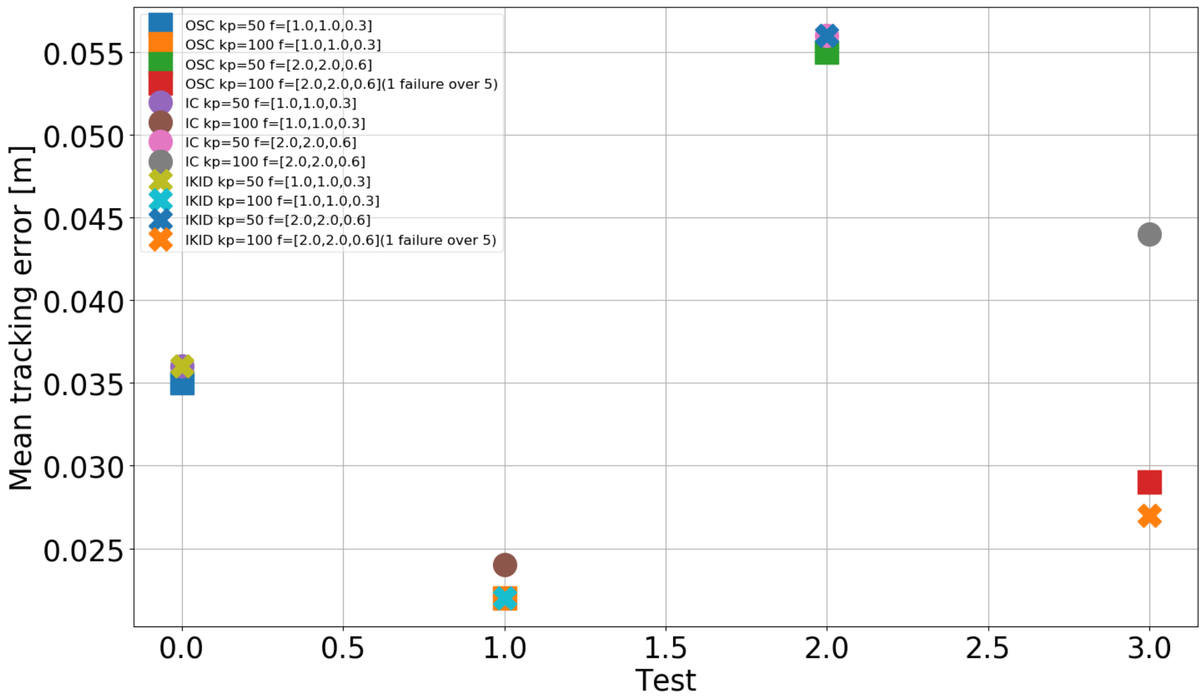

Figure 4: Results with random robot model and postural task.
The results are the average of 5 different simulations.