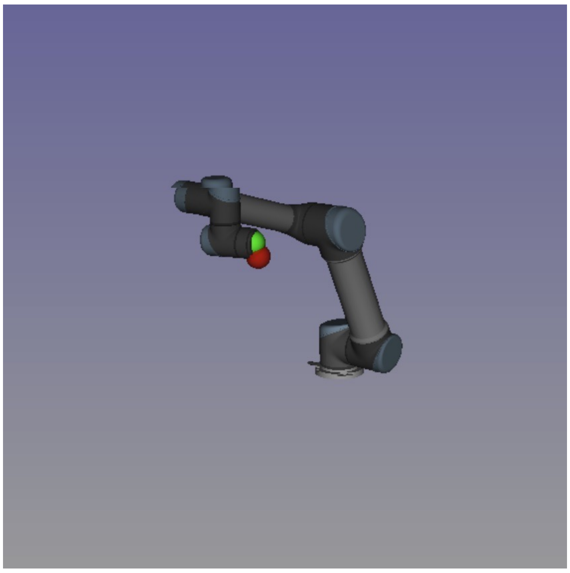
UNIVERSITY OF TRENTO

Industrial Engineering Department

Master of Mechatronics Engineering

Assignment 01: Comparison between different controllers



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1. The performance of control laws are affected by the change of Kp and the frequencies of the reference trajectories. The controllers aren't equally affected by the change of this parameters. At high frequencies of the reference trajectory the best controls are IC (with $Kp = 50$) and IKID (with $Kp = 100$). With $Kp = 50$ there is a worsening of the tracking error when the frequencies are doubled. But with low Kp the IC control law has a minor decrease of performance, compared to IKID and OSC. With $Kp = 100$ it is also shown a woresning of the tracking error doubling the frequencies. In this case the OSC and IKID performs better than IC control. In fig. 1 it is reported the simulation result, test 1 $Kp = 50$ and low frequencies, test 2 $Kp = 100$ and low frequencies, test 3 $Kp = 50$ and high frequencies,test 4 $Kp = 100$ and high frequencies.

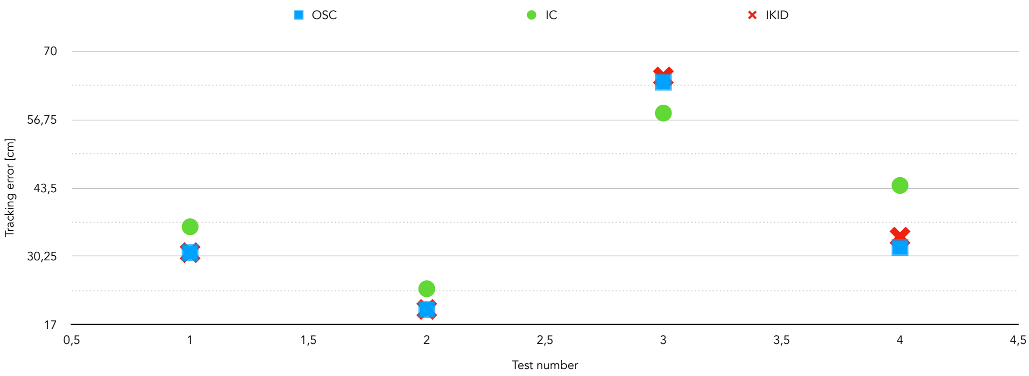

Figure 1: Mean tracking error in differen tests.

2. Changing randomly the inertial paremeters the performance of controllers change as well. Sometimes we have a better tracking error, most of the times it is worse. In fig. 2 it is reported the tracking error of ten tests at low frequencies of the controllers both with $Kp = 50$ and $Kp = 100$. As we can notice the tracking errors are affected, in addition the change is less noticeable with $Kp = 100$. The IKID and OSC has similar behaviour with the first more sensitive to the changes of the inertial parameters. In this case no controllers seems to be more robust with respect to the others. In fig. 3 is reported the tracking error of ten tests at high frequencies of the controllers both with $Kp = 50$ and $Kp = 100$. In this case the statements said before remains valid, but in this case th IC resulst to be way more robust than the other two control laws.

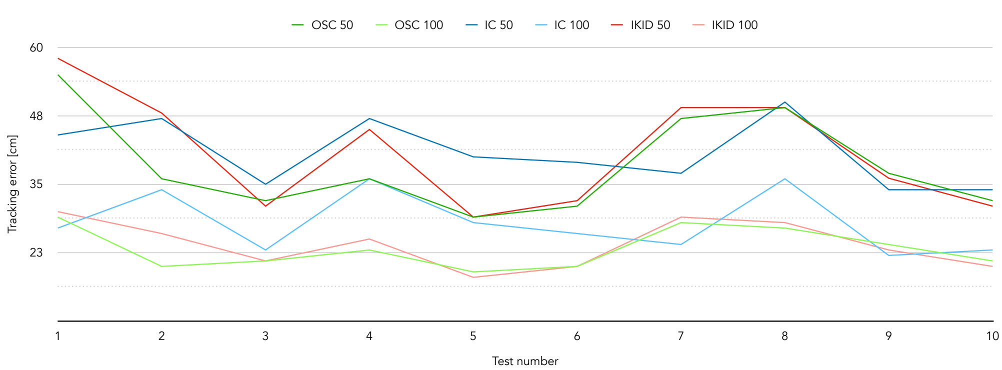

Figure 2: Mean tracking error with low frequencies.

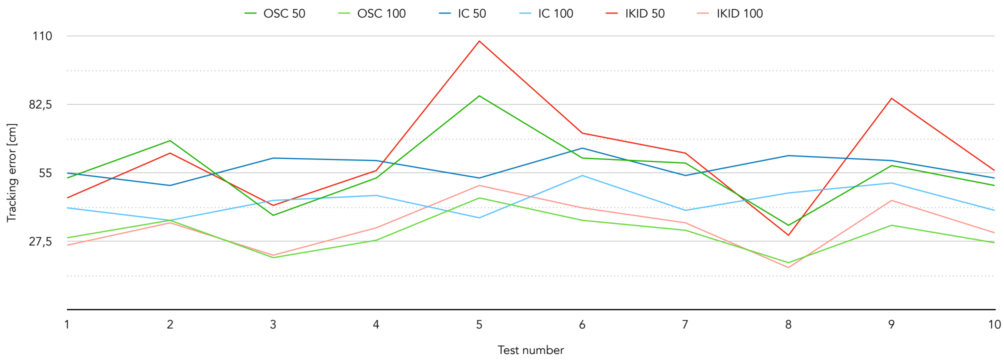

Figure 3: Mean tracking error with high frequencies.

In table 1 are reported the average traking error and the standard deviation of the tests performed previously. As we can see in tehe tests done at low frequencies and with $Kp = 50$ the IC control behaves better, in terms of dispersion, than OSC and IKID. But with higher Kp OSC is better. with high frequencies the better behavior of the IC control is more recognizable, especially with low Kp.

Control law, Kp, frequencies	Mean traking error [cm]	Mean traking error with no uncertainties [cm]	standard deviation [cm]
OSC 50	38	31	9.0
IC 50	41	36	5.7
IKID 50	41	31	10.1
OSC 100	23	20	3.7
IC 100	28	24	5.5
IKID 100	24	20	4.2
OSC 50	56	64	14.7
IC 50	57	58	4.9
IKID 50	62	65	22.3
OSC 100	31	32	7.6
IC 100	44	44	5.9
IKID 100	33	34	10.0

Table 1: Average traking error and standard deviation of of the control laws.

3. Abrupt movements are shown by the control IKID with $Kp = 50$ and high frequencies. To overcome this problem the choice is to change the parameter Kp_j. It doesn't affect the operatonal space dynamics. In practice we are intrested in tracking the reference trajectory with the end-effector, while at the same time we want to stay as close as possible to the q_{ref} position. So acting on the postural task, increasing Kp_j, we require a stronger stabilization of the joint space. This should make the robot sop doing abrupt movements.

4. Increasing Kp_j from 20 to 25 the problem of abrupt movements disappears. With a stronger increase of Kp_j it is shown a slightly decrease of the tracking error. This is due to the fact that the joint angles don't move suddenly anymore and the manipulator is better stabilized with respect to the reference joint position. Nevertheless this increasing in task performance is small, this is due to te little effect that the postural task has on the task of the end-effector. Lastly increasing Kp_j affects positively also OSC control law, while IC is not affected. In fig. 4 it is shown the effect of Kp_j on the tracking error

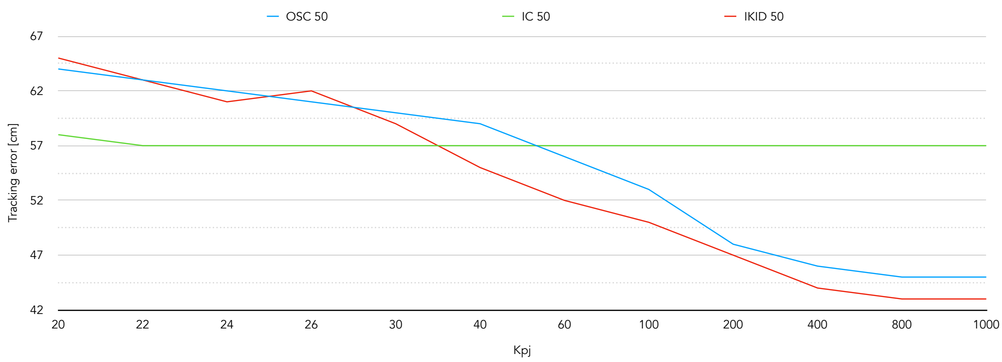

Figure 4: Mean tracking error increasing Kp_j, with $Kp = 50$ and high frequencies.

5. On a real robot I would choose to implement a Impedance Control because it is well suited to avoid large impact forces, so it is a good choice for a robot that works in un unstructured environment with the possibility of collision with people, other machine and objects. Firstly for safety reason the IC control is a better choice rather than OSC and IKID controls that aim to rigidly achieve the decided tasks. In the previous tests the IC control law proved to be worse than the other two for the same value of Kp, so compared to the others IC control needs a higher Kp, with the result of a stiffer behaviour, therefore it will be necessary to find a compromise between the tracking error and the desired dynamics of the robot. IC control law has also shown a more robust behaviour when the inertia parameters of the simulated robot were randomly changed (40%) respect to the model used by the controller. This fact results to be helpful when there is a relatively high model uncertainty, thus making the modeling phase less demanding. In comparison to IC, IKID showed a greater sensitivity to the postural task gain, to uncertainties on the inertia and a greater worsening of performance as the frequencies increase, keeping constant Kp. OSC showed the best performance in the case of no uncertainties, but with the previous tests it is clear that it is less robust than IC, but better than IKID with low Kp_j . Finally the implemented OSC control is computationally heavier than IC and IKID where it is used a simplified control.

One way to increase the performance of the ontrol law is to increase the proportional gain, taking care not to exceed the maximum torque aviable from motors. In figure 5 it is showed the trend of the trackig error as Kp increases, we can see that the IC control is advantageous when Kp is low and, by increasing Kp, the difference with the other controls remains almost constant (with very high values of Kp this difference becomes smaller).

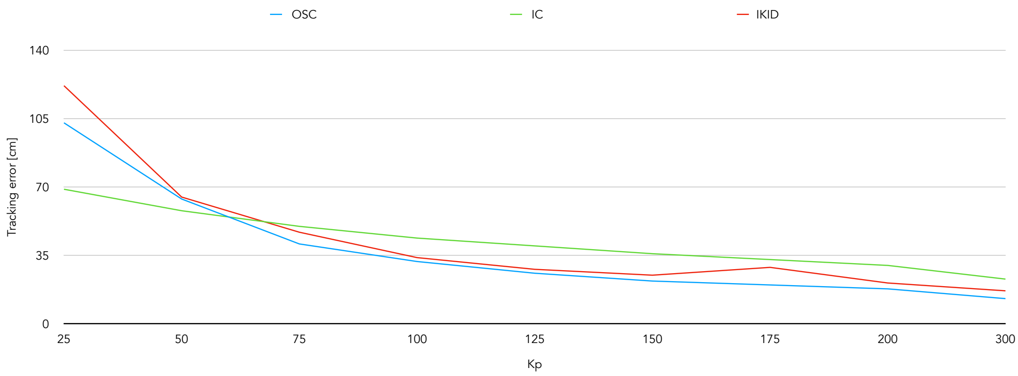

Figure 5: Tracking error of control laws as Kp increases, with high frequencies.

One of the main problems with the IC control law is that the robot could not change its stiffness once it was previously set. One way to resolve this problem should be to vary the stiffness in real time, in particular there are two possibilities. The simplest way is to have the possibility to change this parameter remotely by an operator.
Another way is to implement OSC control, which has better tracking error performance, if the error made about position and speed is below a certain threshold. If this limit is exceeded and therefore an impact is detected, the IC control is activated. The limits for the position and speed error must be finely tuned for the real application. A downside to this implementation is that even though there are no obstacles, but the errors are high, the less efficient control law is still used.