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ROB-UY 2004 – Robotic Manipulation and Locomotion

Final Project Report: Pick and Place Objects

For this project, a controller should be implemented to pick up two red blocks and drop them in the green bowl placed on the same table. The model used was the Frank-Emika Panda robot with 7 revolute joints.

I. *Define Trajectory*

Since the main task was to pick up the blocks, the trajectory of the end-effector should be well defined. Specifically, the gripper should follow a concept of operation as start origin → above block 1 → middle of block 1 → <u>close gripper</u> → above bowl → <u>open gripper</u> → above block 2 → middle of block 2 → <u>close gripper</u> → above bowl → <u>open gripper</u> → return origin.

The gripper should hover above each block before diving down and fetch it to prevent accidentally contacting other objects during movements. Bending down inside the bowl to release the blocks was determined unnecessary since the scenario where the blocks bounced outside was never observed.

A function of `compute_trajectory` was defined to generate desired positions and velocities of the end-effector in the spatial frame. The function utilized time parametrization with acceleration and velocity constraints in order to achieve a smooth moving trajectory.

II. *Control Methods*

It was determined that 7 degrees of freedom was too much for this task. In fact, 3 degrees of freedom was enough for operation, which means only 3 joints needed to stay flexible while the other 4 joints could remain a fixed pattern or orientation.

Fixed Joints

Joint 2 and 4 were programed to have no rotation to help joint 5 maintain vertical to the table, which was crucial to pick up the block for the selected motion moving from top to bottom. On top of that, joint 5 should always follow the expression below to offset the rotation from joint 1 and 3 and maintain vertical:

$$\theta_5 = \theta_1 - \theta_3$$

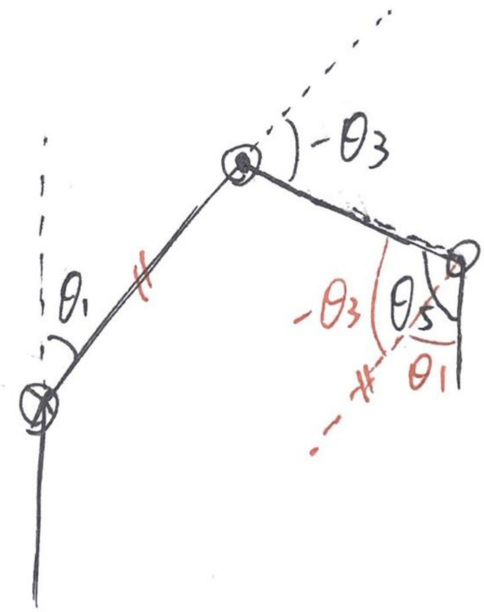

Figure 1: Joint 5 Expression Derived

Joint 6 was also expected to always remain parallel to the edge of the table to allow maximum contact area between the gripper and the block for best pick up probability. Since the angle was already set during initial setup as $\pi/4$, and joint 0 was the only joint left on the same plane, joint 6 would just rotate the same angle as joint 0 to keep the parallel.

$$\theta_6 = \theta_0 + \pi/4$$

The fixed joints were controlled using a PD controller since the desired angles were fixed during the entire operation. The torque for these 4 joints should overwrite any previous controller to enforce the fixed values.

Free Joints

Joint 0, 1, and 3 were the free joints left and either impedance control or resolved-rate control should be applied since the reference position and velocity of the end-effector was known. Impedance control was selected to avoid dealing with singularities and matrix inverse calculations. The measured position and velocity of the end-effector was derived from the robot's forward kinematics method, and the Jacobian of the end-effector with an orientation of the spatial frame was used.

III. *Torque Calculation*

Joint torques were calculated first through impedance control. Then the torques corresponding to the 4 fixed joints were overwritten by the PD controller to ensure a constant angle. Finally, gravity compensation was added, and the values could now be sent to the simulator.

IV. *Results*

The gripper successfully picked up the blocks and dropped them in the green bowl. The position and velocity of the end-effector was plotted and demonstrated a good tracking result on x and z axes. Some oscillations were observed in the y direction. This was probably due to the fact that the curve had the largest span on y axis, but each path was assigned the same time interval.

Overall, the gripper demonstrated a smooth curve without instability during movement.

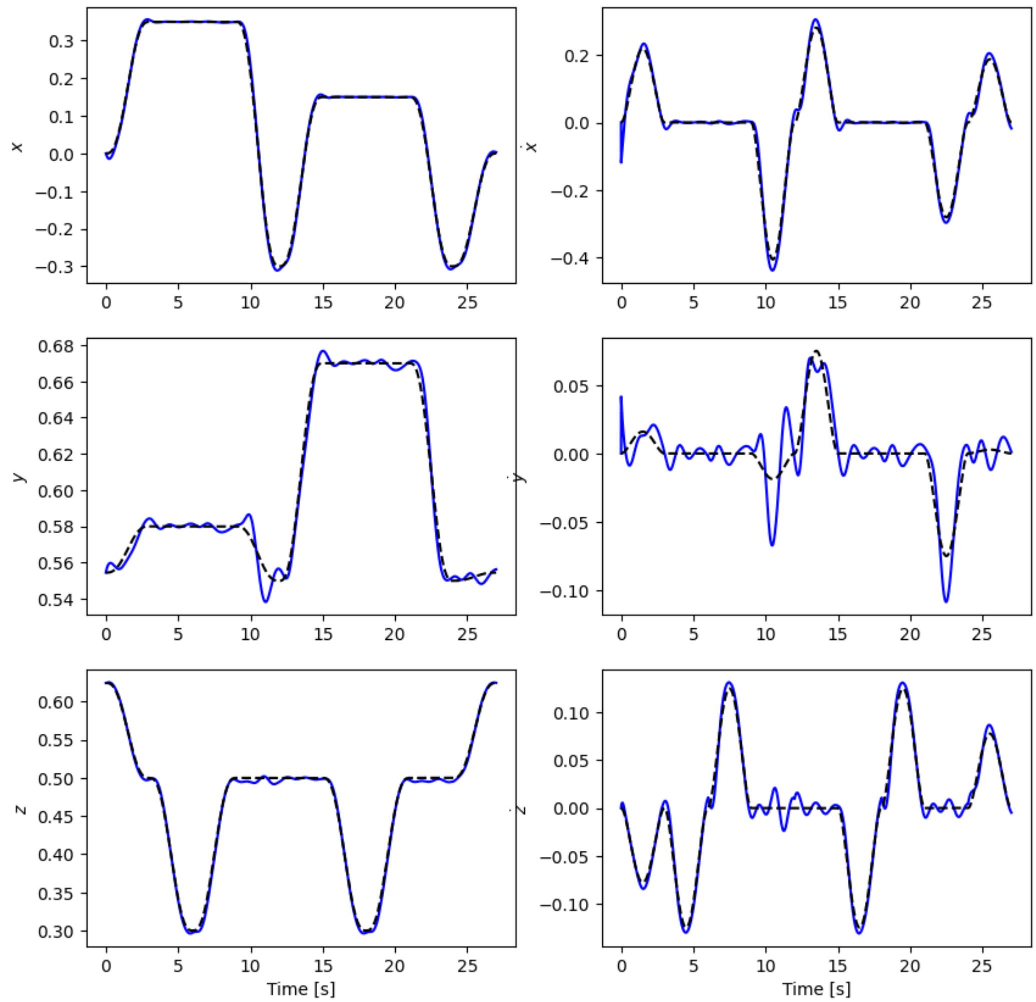

Figure 2: End-effector a) Position b) Velocity over Time in Spatial Frame

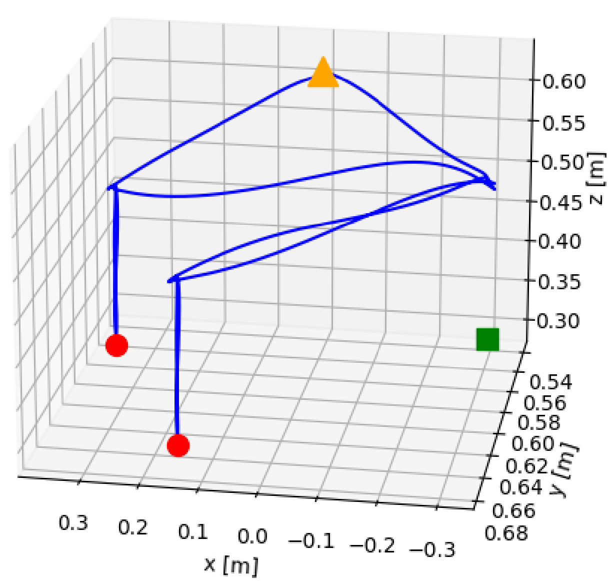

Figure 3: End-effector Trajectory in 3D Spatial Frame