MESISI473424: Cobotics
TP-3 & 4

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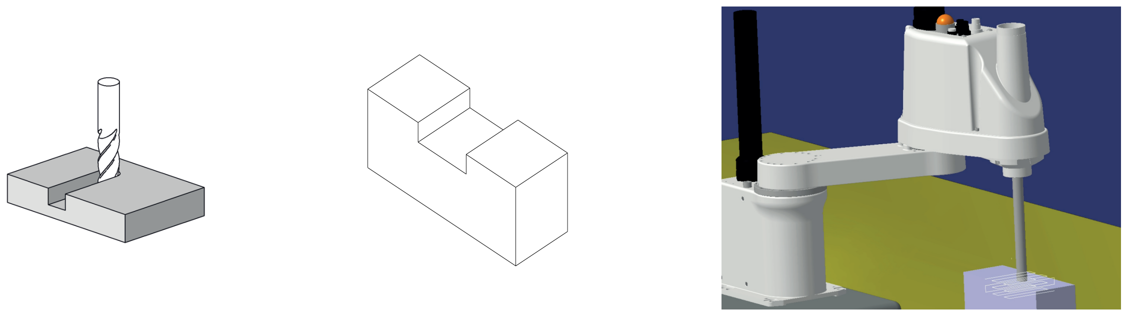
Trajectory planning on a SCARA robot (Continued): Task space simulation

For the TP sessions 3 & 4, we continue to work on the trajectory planning of the SCARA robot from last TP. During this session, we are going to work on Task space simulation by performing a slot-milling operation on a workpiece. Slot milling, also called groove milling, is a machining process where a rotating cutting tool is used to cut a slot in the workpiece (Figure 1a). The slot can be any shape or size, the possibilities are endless. The slot milling cutter and machine, however, should be capable of forming the slot shape in the solid workpiece. We have a workpiece (Figure 1b) of size 200x70x80 mm (PDF provided in DVL: **Spec.pdf**). The objective is to perform a slot milling whose dimensions are given by 65x70x20 mm about the centre of the workpiece. 3D model simulations of the operation is provided as a video file in DVL (**3Dsimulation.avi**). An overview of the task space simulation is shown below in Figure 1c.



(a) (b) (c)

Figure 1: Task space simulation: Slot milling using SCARA robot

Our objective is to perform the task space simulation using the MATLAB file **Scara3D.m**. We will be switching from joint space to task space during this process. You can use the file **Robot.m** to plot the robot workspace as the operation must be planned within the workspace of the robot. Download the additional MATLAB file **jobs.m**. This file consists of the slot-milling trajectory to be performed. Set your robot at the home-position (refer to earlier TP) and also call this file **jobs.m**. Line 13 is the departure point for the trajectory. By default it is set at [-12,25,20]. You can either continue at this position or change it but ensure that the milling coordinates are within the workspace of the robot.
Carry out the following steps in continuation with the previous TP.

8. Perform a joint-space simulation from question-5 with the milling coordinates. What do you

observe? Is it correct to perform the simulation this way or is it necessary to modify any joint value?

9. After finishing the joint space simulation, perform a task space simulation to move the robot to the departure point of milling operation. This is achieved by solving the inverse kinematic problem (IKP). Provide the solution for the IKP for the SCARA robot. You can use the same frequency and simulation time t_f from the joint space simulation. In order to make things simpler, it is advisable to write a function **IKP.m** for solving the inverse kinematics for each position of the end-effector.

10. From the departure point, continue to perform the task space simulation for the milling operation. The coordinates of end-effector are available from the function **jobs.m**.

11. Once the milling operation is completed, perform a joint space simulation. It is advisable to first move the prismatic joint to zero. Followed by that, the robot can be moved back to its home position.

12. During the entire simulation sequence, plot the joint positions, velocities and accelerations (degrees & mm). For the joint space simulation, these plots can be easily generated. For the task space simulation, we need to calculate the Jacobian matrix, its inverse and also its time-derivative. The equations are given by:

$$\begin{aligned}
\dot{\mathbf{X}} &= \mathbf{J}\dot{\mathbf{q}}(t) \\
\dot{\mathbf{q}}(t) &= \mathbf{J}^{-1}\dot{\mathbf{X}} \\
\ddot{\mathbf{q}}(t) &= \mathbf{J}^{-1}\ddot{\mathbf{X}} - \mathbf{J}^{-1}\dot{\mathbf{J}}\dot{\mathbf{q}}(t)
\end{aligned}$$

Here, $\mathbf{J}^{-1}$ can be computed with the function **pinv** in MATLAB. Pseudo-inverse is employed when we do not have a square matrix and also when a robot is non-redundant. $\dot{\mathbf{J}}$ is the time derivative of the Jacobian matrix.

13. Generate the solutions to the DKP during each instance of the simulation.

Information & Dates

1. The deadline for submission (TP-1 to 4) is on 17.11.2024 (by 23h59)
2. The document should be drafted properly as a PDF with explanations, supporting codes and plots.
3. One submission per group is sufficient
4. Video files can be provided and will be a bonus.