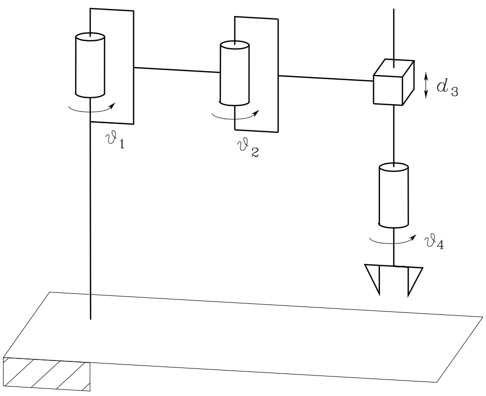
FOUNDATIONS OF ROBOTICS
(Prof. Bruno SICILIANO: Academic Year 2024–2025)

Master's Courses in Automation Engineering and Robotics + Biomedical Engineering

TECHNICAL PROJECT

Student(s): ______________________________

Consider the SCARA manipulator in the figure



with the following data:

$$d_0 = 1\,\text{m} \quad a_1 = a_2 = 0.5\,\text{m} \quad \ell_1 = \ell_2 = 0.25\,\text{m}$$

$$m_{\ell_1} = m_{\ell_2} = 20\,\text{kg} \quad m_{\ell_3} = 10\,\text{kg}$$

$$I_{\ell_1} = I_{\ell_2} = 5\,\text{kg}\cdot\text{m}^2 \quad I_{\ell_4} = 1\,\text{kg}\cdot\text{m}^2$$

$$k_{r1} = k_{r2} = 1 \quad k_{r3} = 50\,\text{rad/m} \quad k_{r4} = 20$$

$$I_{m_1} = I_{m_2} = 0.01\,\text{kg}\cdot\text{m}^2 \quad I_{m_3} = 0.005\,\text{kg}\cdot\text{m}^2 \quad I_{m_4} = 0.001\,\text{kg}\cdot\text{m}^2$$

$$F_{m1} = F_{m2} = 0.00005\,\text{N}\cdot\text{m}\cdot\text{s/rad} \quad F_{m3} = 0.01\,\text{N}\cdot\text{m}\cdot\text{s/rad} \quad F_{m4} = 0.005\,\text{N}\cdot\text{m}\cdot\text{s/rad}$$

- Analyze velocity and force manipulability for the supporting structure, plotting the relative ellipsoids for a significant number of positions of the end-effector within the workspace.
- Plan the trajectory along a path characterized by at least 15 points within the workspace, in which there are at least one straight portion and one circular portion and also the passage for at least 3 via points.
- Implement the CLIK algorithms in MATLAB with both Jacobian inverse and transpose along the trajectory. Adopt Euler numerical integration rule with sampling period of 1 ms.
- Assuming to relax an operational space component, implement the CLIK algorithm in MATLAB with Jacobian pseudo-inverse along the trajectory when optimizing a dexterity constraint.
- Derive the dynamic model by assuming that the angular velocity of each rotor is only due to its own spinning.
- Consider a concentrated end-effector payload of about 5 kg. Then, design: 1) a robust control; 2) an adaptive control; 3) an operational space inverse dynamics control with the adoption of an integral action to recover the steady-state error due to the uncompensated load. Simulate in MATLAB the motion of the controlled manipulator under the assumption that the desired joint trajectories for the first two controllers are generated with a 2nd-order CLIK algorithm. Implement discrete-time controllers with a sampling period of 1 ms.