UNIVERSITÄT HEIDELBERG
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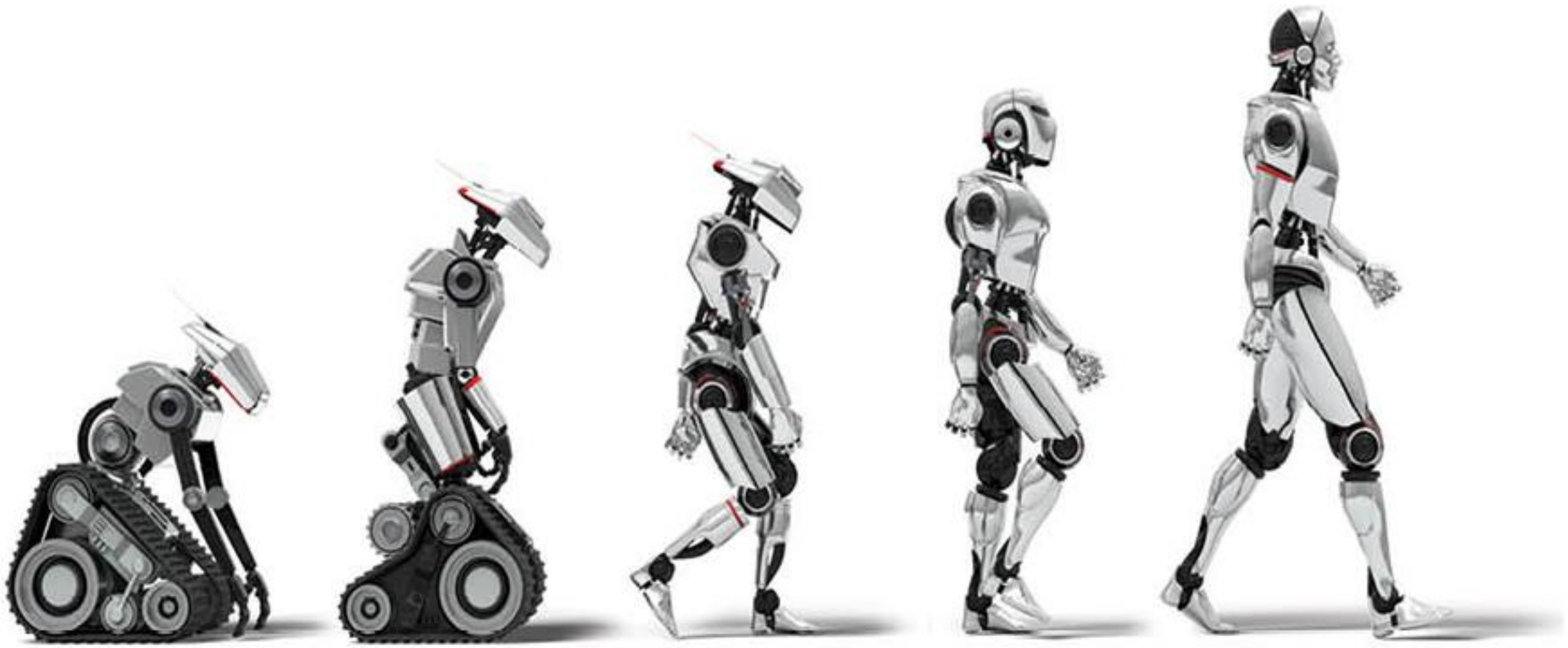
Exercises Robotics 10

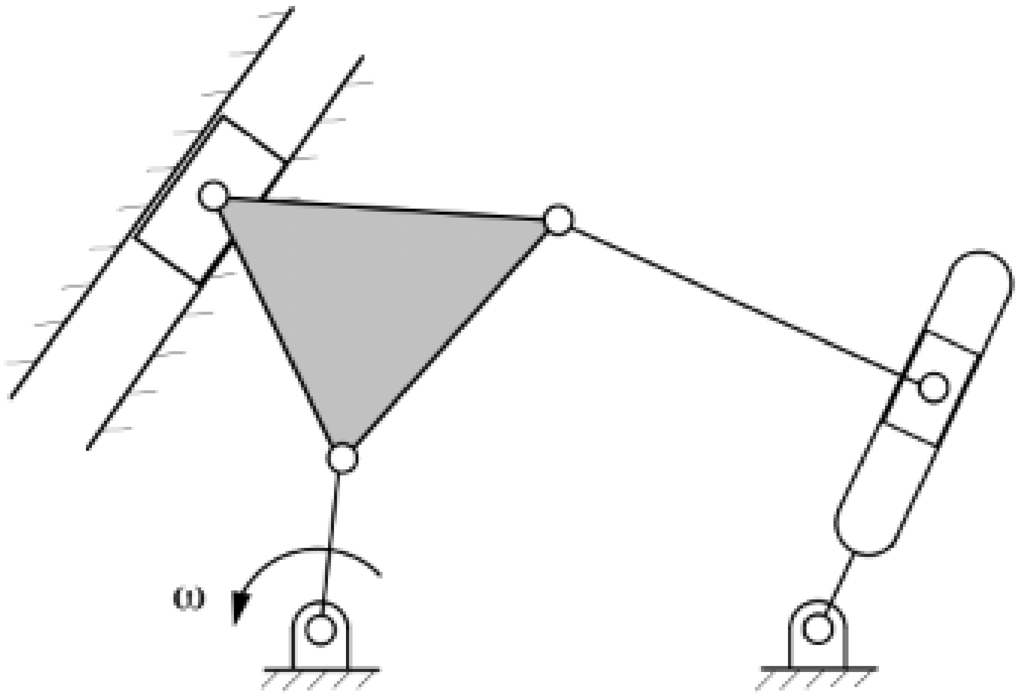


Grübler’s equation

Consider the following mechanism, define:

- The number of links;
- The number of kinematics joints stating the type and the constraints that they allow;

Apply then the Grübler’s formula and show the number of DOF allowed by the mechanism.



Rotation Matrix

A frame $RF_B = \{\boldsymbol{O}_B, \boldsymbol{x}_B, \boldsymbol{y}_B, \boldsymbol{z}_B\}$ is displaced and rotated with respect to a fixed reference frame $RF_A = \{\boldsymbol{O}_A, \boldsymbol{x}_A, \boldsymbol{y}_A, \boldsymbol{z}_A\}$. The displacement is represented by the vector

$$^{A}\mathbf{p}_{O_A O_B} = \begin{pmatrix} 3 & 7 & -1 \end{pmatrix}^T \qquad [\mathrm{m}],$$

while the orientation of RF_B with respect to RF_A is represented by the following sequence of three Euler $ZY'X''$ angles

$$\alpha = \frac{\pi}{4}, \qquad \beta = -\frac{\pi}{2}, \qquad \gamma = 0 \qquad [\mathrm{rad}].$$

For a given point P, provide the value of vector $^{A}\mathbf{p}_{O_A P}$ knowing that its position with respect to frame RF_B is given by

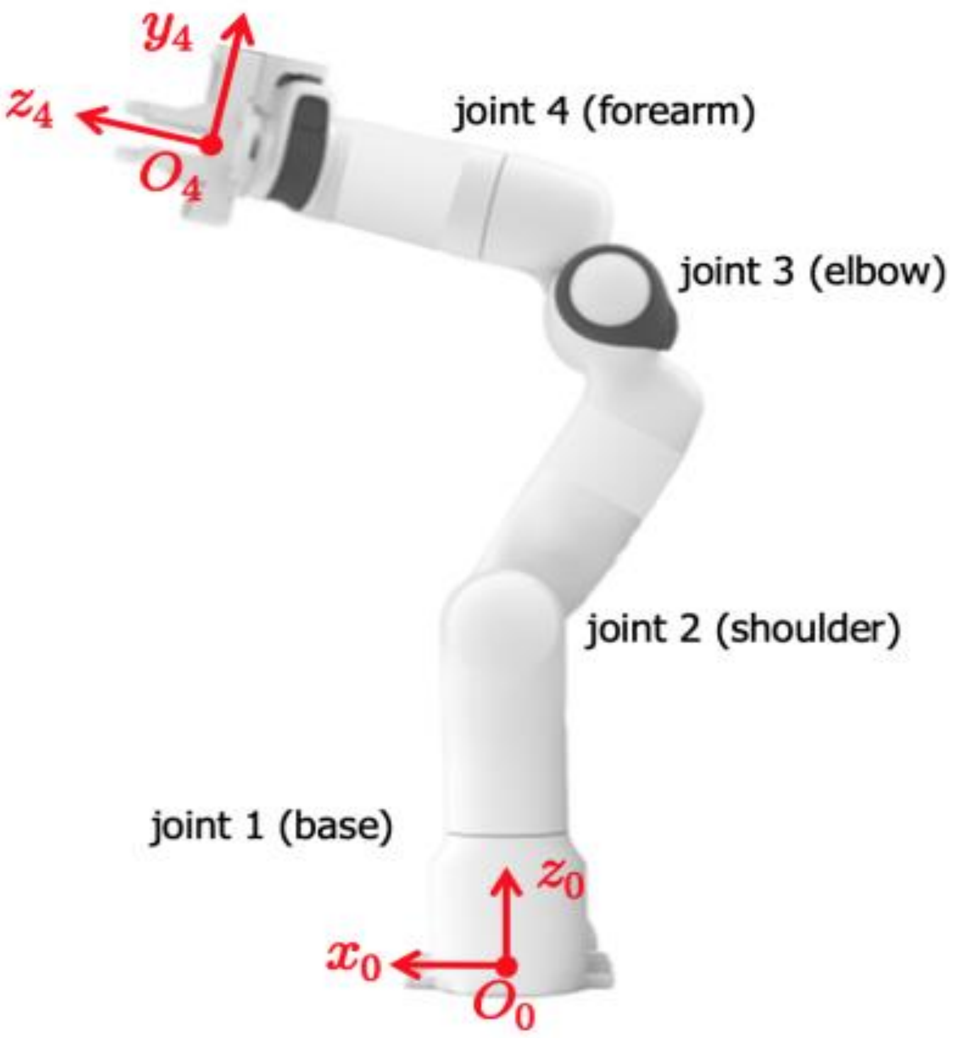
$$^{B}\mathbf{p}_{O_B P} = \begin{pmatrix} 1 & 1 & 0 \end{pmatrix}^T \qquad [\mathrm{m}].$$

Rotation Matrix

$$\boldsymbol{R}_z(\alpha)=\begin{pmatrix}\cos\alpha & -\sin\alpha & 0\\ \sin\alpha & \cos\alpha & 0\\ 0 & 0 & 1\end{pmatrix},\quad \boldsymbol{R}_y(\beta)=\begin{pmatrix}\cos\beta & 0 & \sin\beta\\ 0 & 1 & 0\\ -\sin\beta & 0 & \cos\beta\end{pmatrix},\quad \boldsymbol{R}_x(\gamma)=\begin{pmatrix}1 & 0 & 0\\ 0 & \cos\gamma & -\sin\gamma\\ 0 & \sin\gamma & \cos\gamma\end{pmatrix},$$

$${}^A\boldsymbol{T}_B=\begin{pmatrix}{}^A\boldsymbol{R}_B & {}^A\boldsymbol{p}_{O_A O_B}\\ \boldsymbol{0}^T & 1\end{pmatrix}=\begin{pmatrix}0 & -\sqrt{2}/2 & -\sqrt{2}/2 & 3\\ 0 & \sqrt{2}/2 & -\sqrt{2}/2 & 7\\ 1 & 0 & 0 & -1\\ 0 & 0 & 0 & 1\end{pmatrix}.$$

Exercises D-H



Exercises D-H

a) Assign the link frames according to the Denavit-Hartenberg (DH) convention and complete the associated table of parameters, specifying the signs of all constant symbolic parameters.

b) Write explicitly the resulting DH homogeneous transformation matrices $A_1^0(q_1)$ to $A_4^3(q_4)$ and compute in an efficient way the direct kinematics $p_4 = p_4(q) \in \mathbb{R}^3$ for the position of the origin O_4.

c) Sketch the robot in the stretched upward configuration and specify which is the associated configuration q_s in your DH convention. Compute then $p_s = p_4(\, q_s)$.

d) In the configuration $q_0 = 0$ determine the expression in the base frame of the absolute position of a Tool Center Point (TCP) which is defined in the end-effector frame by $p_{4,TCP} = [0\ 0.1\ 0.2]^T\, [m]$.

Thank you for your Attention!!!