Industrial Robotics – Exercises for Chapter 3, Kinematics

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Exercise 3.1: Homogeneous transformation

A coordinate system B is shifted by (10,0,10) relative to coordinate system A and rotated 45° relative to the z-axis.

1. Calculate the coordinates of the point P – given in KS B with (2,2,2) – in coordinate system A
2. Check your calculations by performing the back calculation using the inverse transformation matrix.

Exercise 3.2: Simple kinematics

Given is a simple kinematics according to the illustration below. Calculate the coordinates of TCP in the specified coordinate system, for:

1. d=20, alpha=0°, theta=0°
2. d=10, alpha=0°, theta=90°
3. d=20, alpha=90°, theta=0°

To do this, use the homogeneous coordinate transformation.

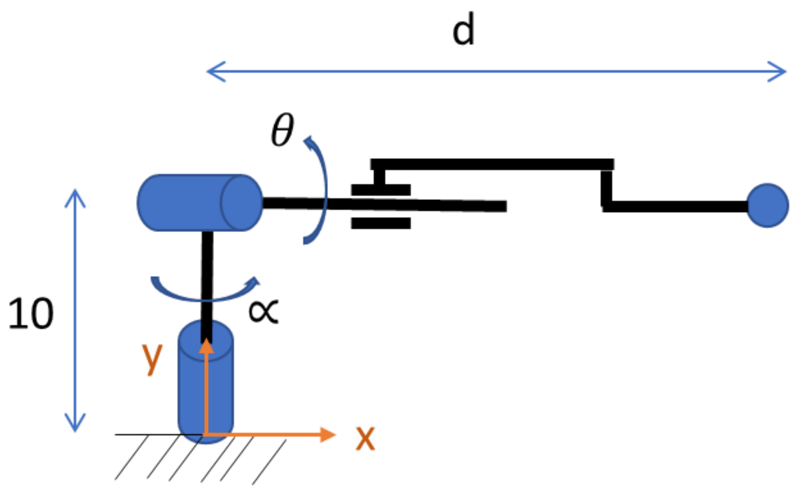


Fig. 1: Simple kinematics

Exercise 3.3: DH Transformation Matrix

In a symbolic calculation with Python and SymPy, prove that the transformation consisting of the folllowing steps:

1. a translation along the z-axis: d,
2. a rotation about the z-axis: δ,
3. a translation along the x-axis: a and
4. a rotation around the x-axis: α

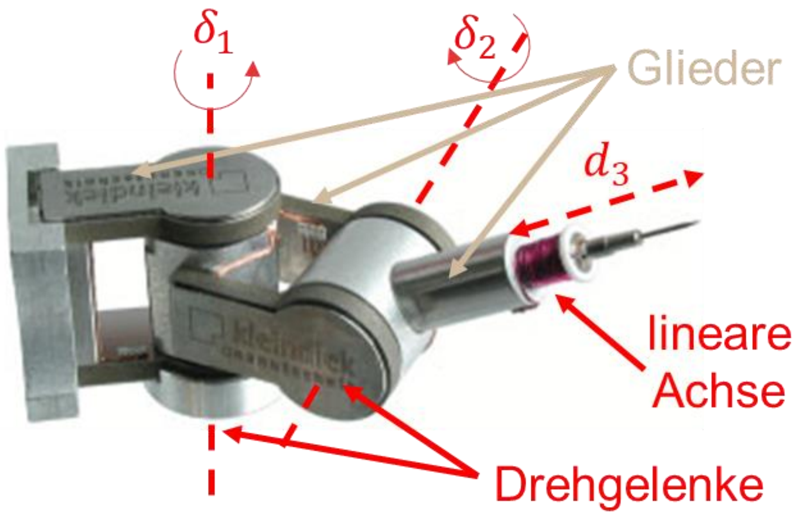
results in the DH transformation matrix in the form:

$$T_i^{i-1} = \begin{pmatrix} \cos\delta_i & -\sin\delta_i\cos\alpha_i & \sin\delta_i\sin\alpha_i & a_i\cos\delta_i \\ \sin\delta_i & \cos\delta_i\cos\alpha_i & -\cos\delta_i\sin\alpha_i & a_i\sin\delta_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Exercise 3.4: Kleindiek microrobot

For the Kleindiek microrobot from the lecture, implement the forward kinematic as a Python program with SymPy. The constructive length of the 1st link should be 25 mm, the distance from the 2nd swivel joint to the thrust joint also 25 mm and the push joint can be extended from 10-30mm.

Test the program and the kinematics for correctness by inserting values and checking for plausibility.



Exercise 3.5: Simple articulated manipulator

Fig. 2 shows a simple articulated manipulator arm. This is to be analyzed with the Denavit-Hardenberg method.

1. Sketch a model to determine the DH transformation parameters from its base to the TCP. Use the coordinate system of the gripper tip as the TCP's coordinate system. Note the relevant quantities (distances, angles, axes, etc.) in the sketch.
2. Determine DH parameters
3. Use Python and SymPy to create a forward kinematics calculation program.
4. What is the position of the point $(1,3,5)^{TCP}$ in world coordinates if the following joint parameters are given: $\theta_1=\pi/2$, $\theta_2=\pi/2$, $\theta_3=-\pi/2$? Draw the orientation of the robot.

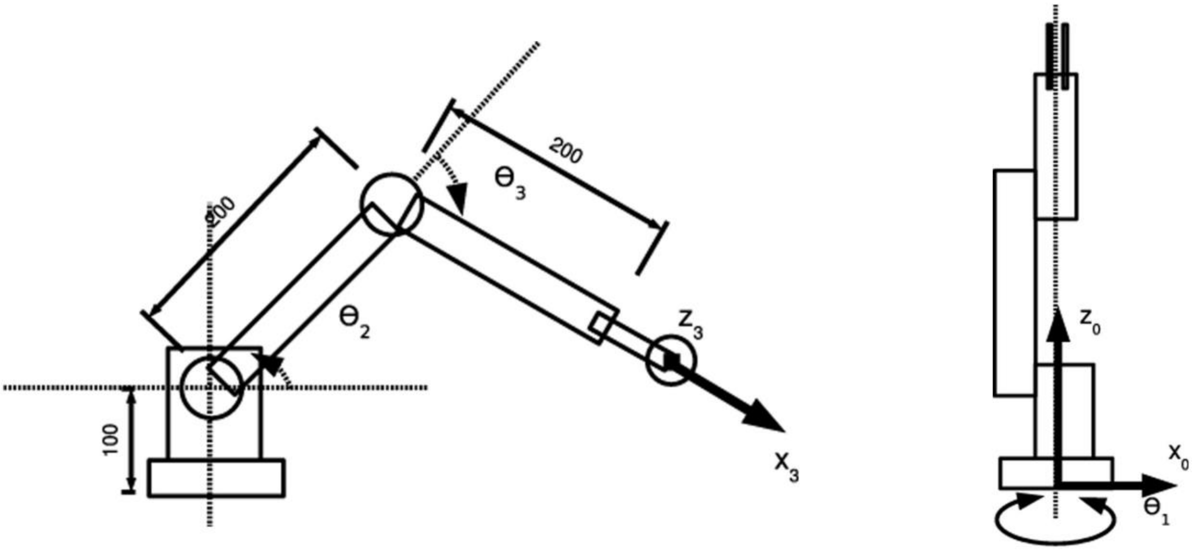


Fig. 2: Simple articulated manipulator arm, side view (left figure), front view (right figure)

Exercise 3.6: Skara robot

Fig. 3 shows a Skara robot. Analyze it using the Denavit-Hardenberg method.

1. Sketch a model to determine the DH transformation parameters and note the relevant quantities (distances, angles, axes, etc.) in the sketch.
2. Determine the DH parameters
3. Use Python and SymPy to create a forward kinematics calculation program.
4. What is the position of the point $(1,3,5)^{TCP}$ in world coordinates if the following joint parameters are given:
   z_1=100 mm, $\theta_1=\pi/2$, $\theta_2=-\pi/2$, $\theta_3=+\pi/2$?

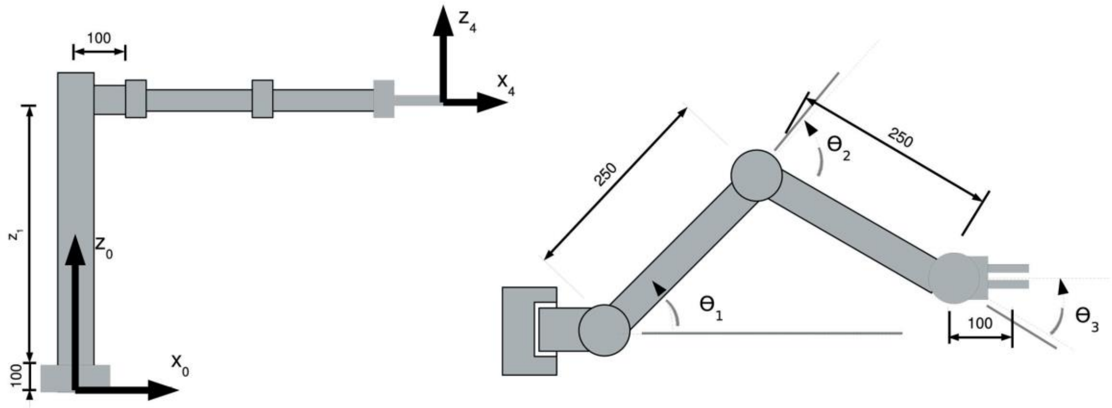


Fig. 3: Skara robot, side view (left image), top view (right image)