Introduction to Robotics

Assignment #3

Due: 15.06.2020, 23:59

Task 3.1 (4 points) Screw Cap: Consider a simple gripper that is being used to loosen/open a screw cap (illustrated in figure 1). The thread height of the screw cap is given as $\frac{h}{\#rotations}$.

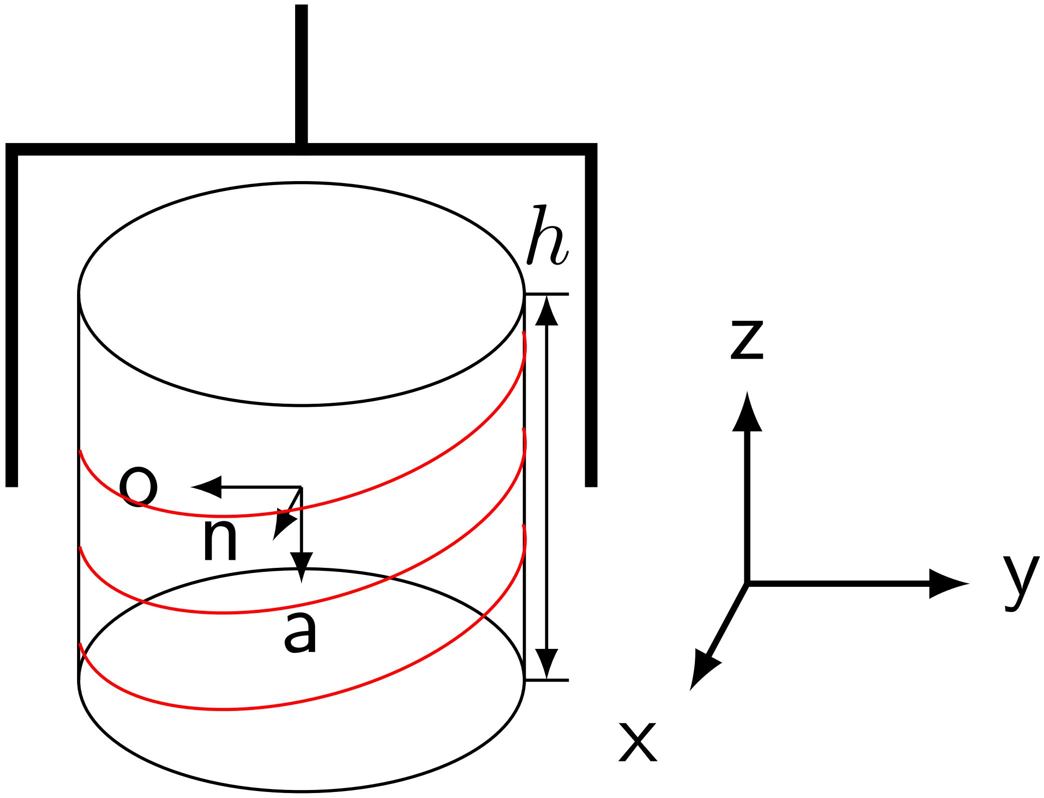

Figure 1: Loosening of a screw cap.

Determine the time-dependent homogeneous transformation

$$T(t) = \begin{bmatrix} n_1(t) & o_1(t) & a_1(t) & d_1(t) \\ n_2(t) & o_2(t) & a_2(t) & d_2(t) \\ n_3(t) & o_3(t) & a_3(t) & d_3(t) \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

that describes the motion of the manipulator. Ignore the acceleration and deceleration phases and choose the z-axis to be the axis of the rotating motion. Furthermore, assume the angular velocity ω_z to be constant.

Task 3.2 (4 points) DH-Paremeters: Figure 2 shows a manipulator with three degrees of freedom. The position of the manipulator endpoint is specified by the vector

$$\mathbf{r} = [r_x, r_y, r_z]^T$$

The position vector is specified with respect to the coordinate frame Σ_0.

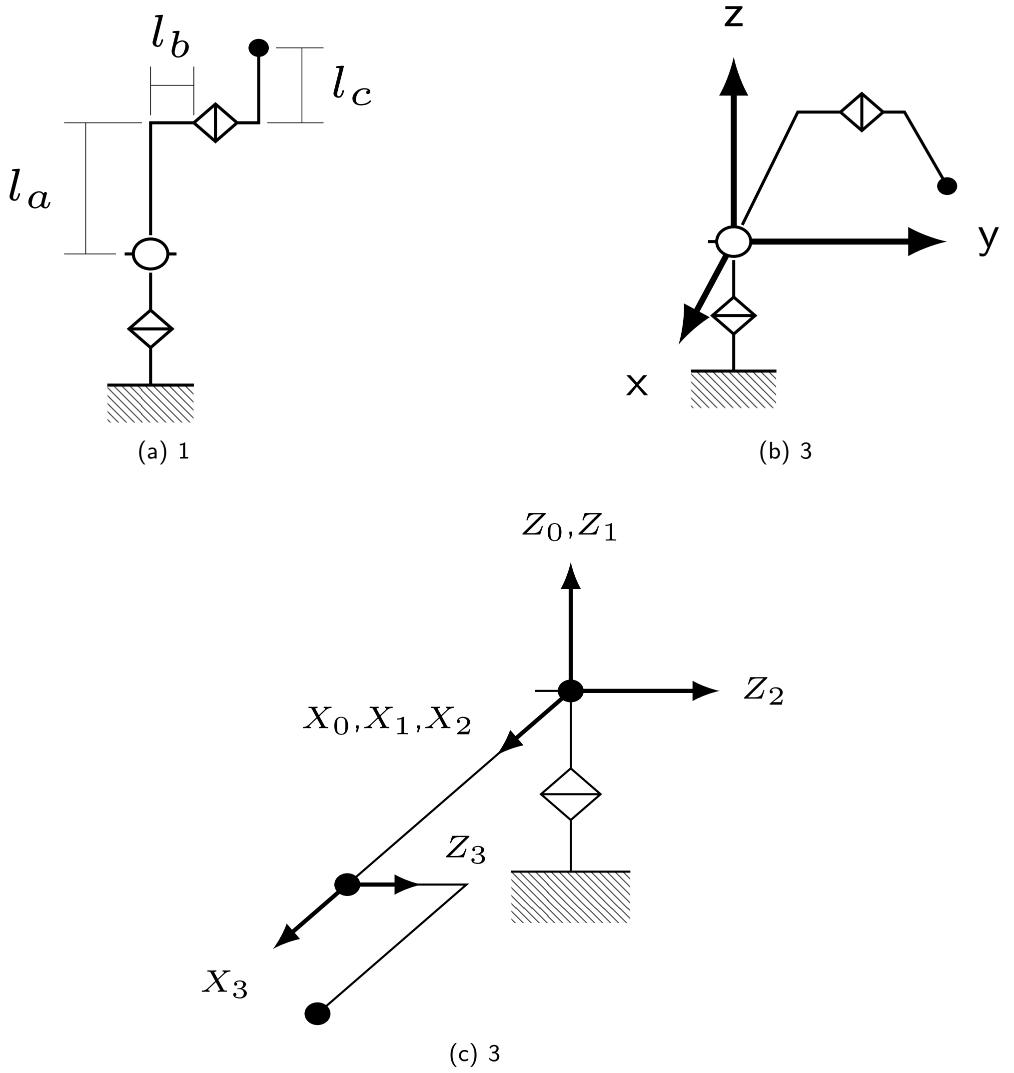

Figure 2: (a) Manipulator sizing. (b) Position of the manipulator endpoint. (c) Manipulator geometry.

3.2.1 (2 points): Determine the DH parameters of the given manipulator. Use a table to present the determined DH parameters.

3.2.2 (2 points): From the table, derive ${}^0T_3$.

Task 3.3 (3 points) Repetition precision: Various manufacturers of robot manipulators specify the trajectory precision of the manipulator based on the repeatability derived from a series of recorded joint angles. Multiple applications (e.g. previous task) on the other hand require knowledge of the positioning accuracy in order to reach a position in Cartesian space based on information from the vision system.

What factors does the positioning accuracy depend on? (Describe at least 2)

What can be considered a limit of the positioning accuracy, especially in combination with vision systems? (Describe at least 3)

Explain your answers.

Task 3.4 (5 points) Singularities: In the lecture, two different types of singularities were discussed. Describe **two** different kinds of singular configurations for **each** type of singularities and describe the differences between them.

Discuss the difference between singularities and self-collisions for manipulators.

Task 3.5 (9 points) Jacobian and singularities: Figure 3 shows a 2-joint planar manipulator with the following constraints: $10° \leq \theta_1 \leq 350°$, $0° < \theta_2 < 360°$ and $l_1 > l_2$.

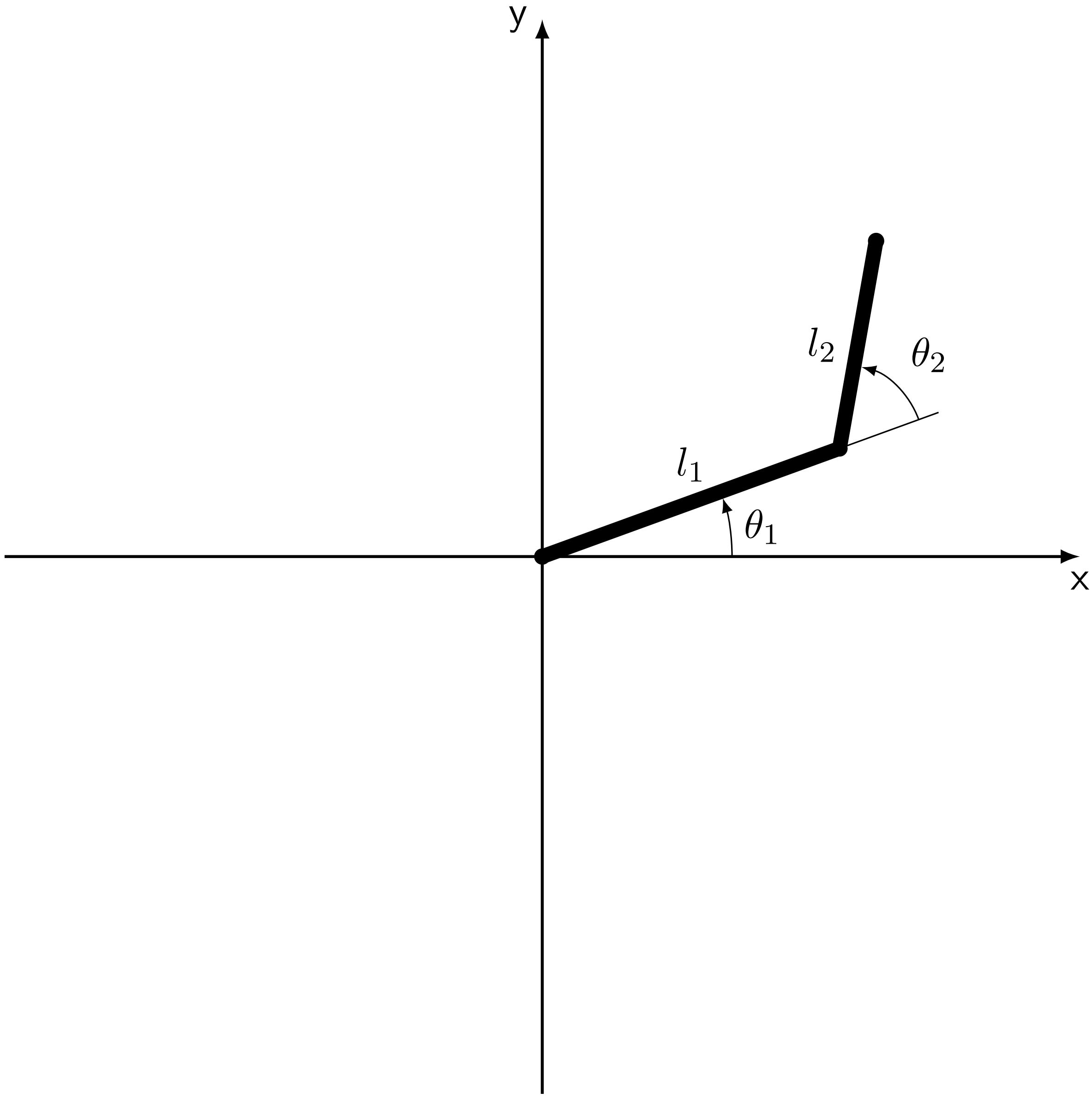

Figure 3: 2-joint planar manipulator.

3.5.1 (2 points): Illustrate the workspace of the manipulator.

3.5.2 (3 points): Determine the Jacobian matrix for the manipulator.

3.5.3 (2 points): Determine the singular configurations of the manipulator (mathematically or geometrical).

3.5.4 (2 points): Outline and explain the determined singular configurations (mathematically or geometrical).

Task 3.6 (2 points) Jacobian: Extend the Jacobian matrix for the 3-joint planar manipulator shown in figure 4.

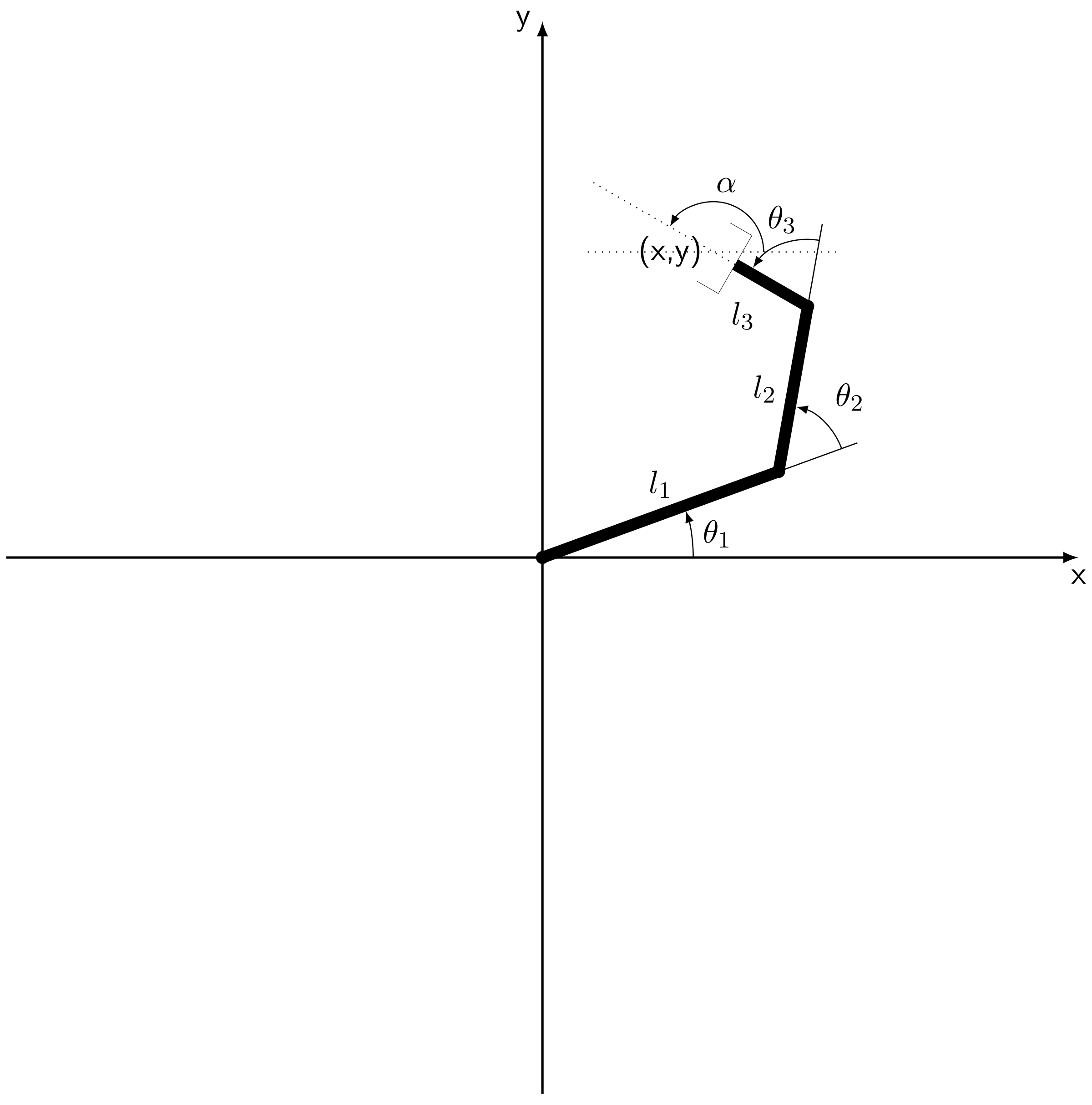

Figure 4: 3-joint planar manipulator.

Task 3.7 (4 points) Singularities of a PUMA560: Consider a PUMA560 manipulator as shown in figure 5. Explain at least three of the possible singular configurations!

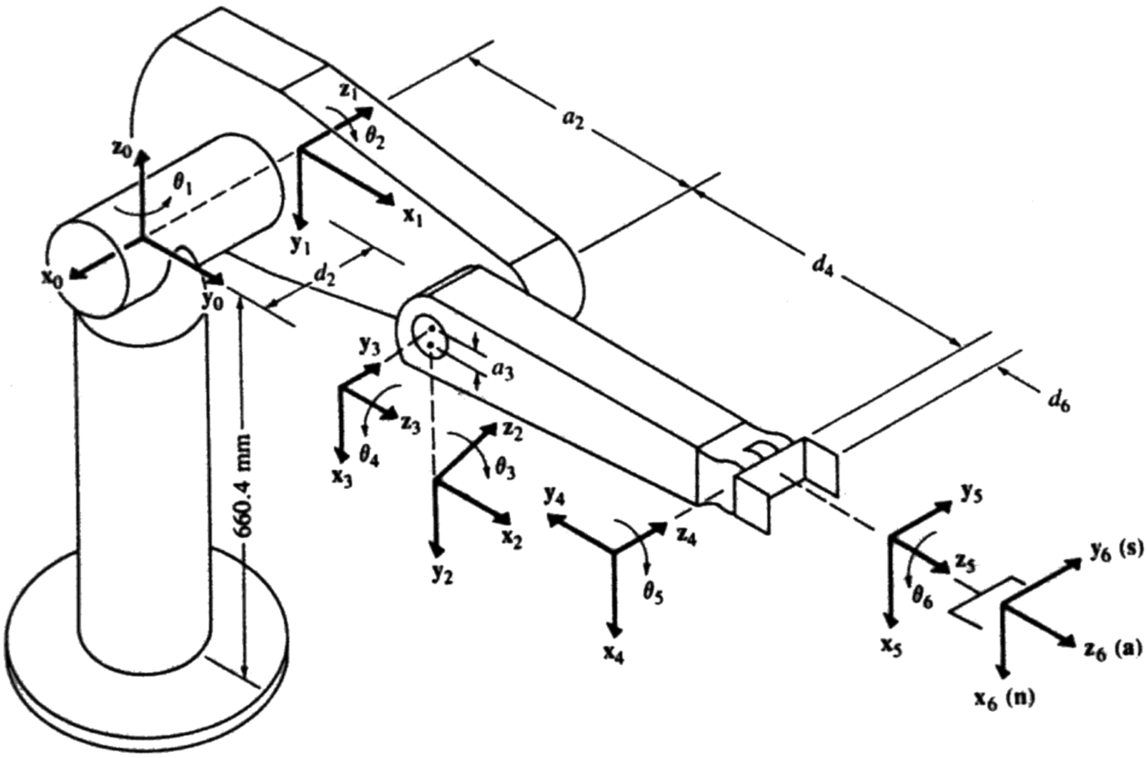

Figure 5: PUMA560 manipulator.

Hint: `Workspace boundary singularities` occur whenever the manipulator is fully extended or is folding back onto itself.

`Workspace-internal singularities` occur if two or more joint axes enter a collinear configuration.