Introduction to Robotics

Assignment #3

Due: 21.05.2019, 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 $\frac{h}{\#rotations}$.

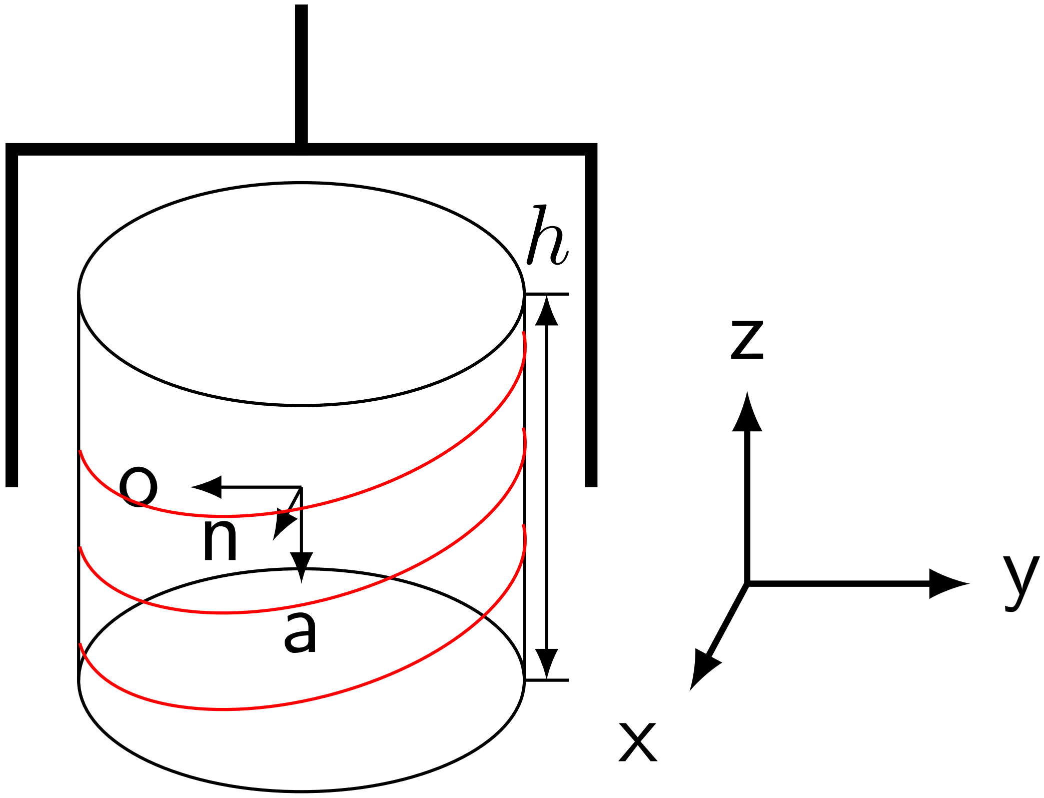


Figure 1: Loosening of a screw cap.

Determine the time-dependent homogeneous transformation

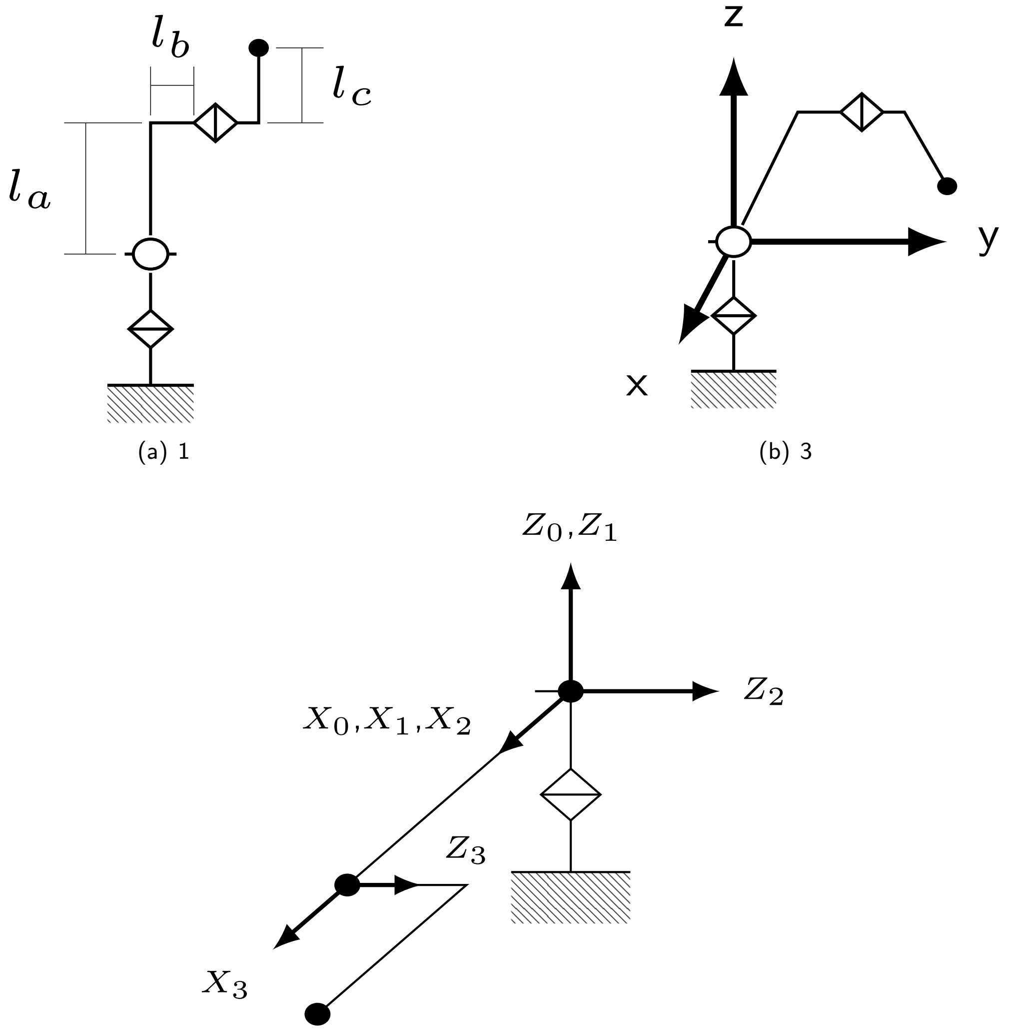
$$T(t) = \begin{bmatrix} n_1(t) & o_1(t) & a_1(t) & d_1(t) \\ n_2(t) & o_2(t) & a_2(t) & d_2(t) \\ n_3(t) & o_3(t) & a_3(t) & d_3(t) \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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.



(a) 1 (b) 3 (c) 3

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 (4 points) Grasping from Camera: Figure 3 shows the workspace of a robot manipulator. Objects transported on a conveyor belt are evaluated by the vision system (a camera) and based on the results of the evaluation the manipulator is used to place the object into either the "Pass" or the "Reject" area.

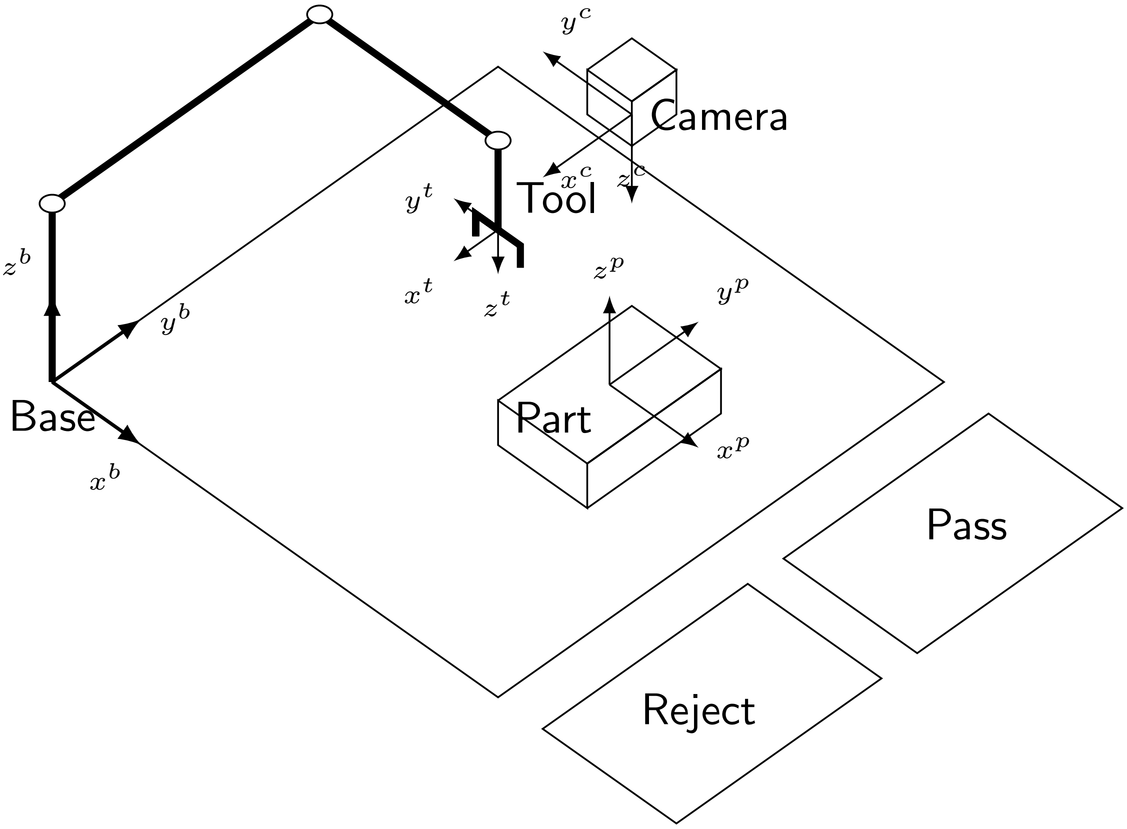


Figure 3: A robot workspace.

The transformation between the object coordinate frame and the camera coordinate frame is known based on camera calibration (see equation 1), the transformation between the base of the robot manipulator and the camera coordinate frame is known as well (see equation 2)

$$^{camera}T_{object} = \begin{bmatrix} 0 & -1 & 0 & 17 \\ -1 & 0 & 0 & -7 \\ 0 & 0 & -1 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1) \qquad ^{camera}T_{base} = \begin{bmatrix} 0 & -1 & 0 & 28 \\ -1 & 0 & 0 & 11 \\ 0 & 0 & -1 & 8 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (2)$$

3.3.1 (2 points): Determine the homogeneous transformation $^{base}T_{object}$.

3.3.2 (2 points): Determine $^{base}T_{tool}$ considering that the manipulator is grasping the object using the front and the back surface of the object. (Hint: the origins of the object and the tool coordinate frames coincide during the grasp).

3.3.3 *Bonus* (4 points): Assume the robot to be a PUMA 560. Calculate a possible joint configuration which fulfills the above target. Assume all values in cm (Hint: you may find materials on the course website useful)

Task 3.4 (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 3.5 (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.