

## Introduction to Robotics

### Assignment #4

Due: 10.06.2015, 13.00

**Task 4.1 (5 points) Jacobian:** Determine the Jacobian matrix for the 3-joint planar manipulator shown in figure 1.

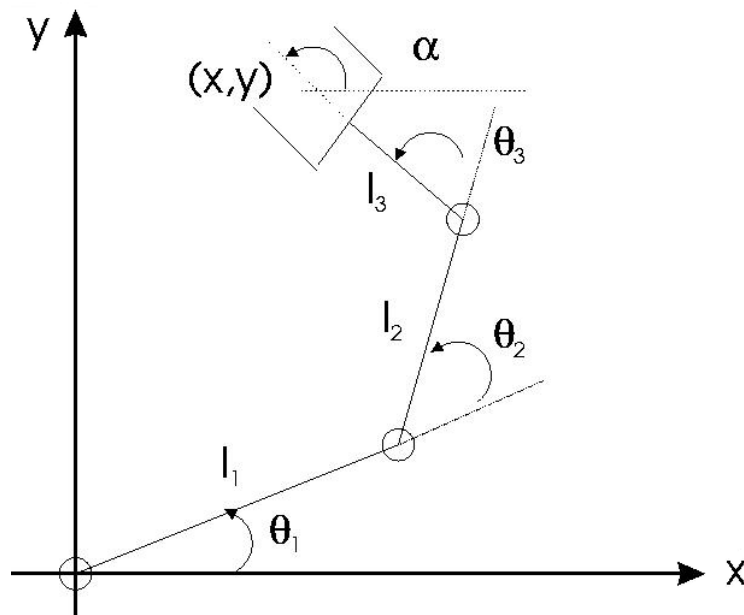


Figure 1: 3-joint planar manipulator.

**Task 4.2 (6 points) Jacobian and singularities:** Figure 2 shows a 2-joint planar manipulator with the following constraints:  $0^\circ \leq \theta_1 < 360^\circ$ ,  $0^\circ \leq \theta_2 < 360^\circ$  and  $l_1 > l_2$ .

**4.2.1 (1 point):** Illustrate the workspace of the manipulator.

**4.2.2 (2 points):** Determine the Jacobian matrix for the manipulator.

**4.2.3 (1 point):** Determine the singular configurations of the manipulator.

**4.2.4 (2 points):** Outline and explain the determined singular configurations.

**Task 4.3 (4 points) Singularities of a PUMA560:** Consider a PUMA560 manipulator as shown in figure 3. Explain at least three of the possible singular configurations!

**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.

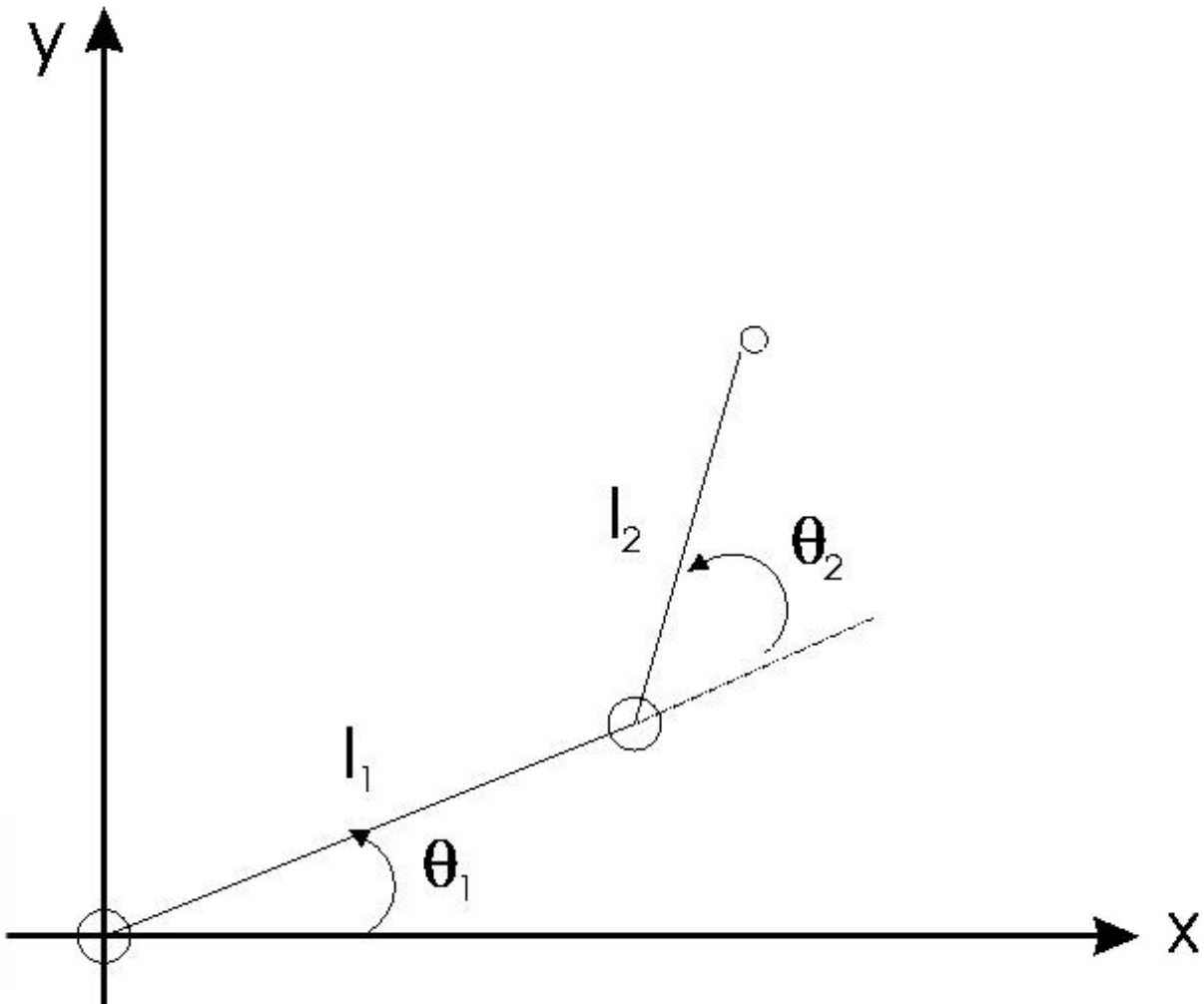


Figure 2: 2-joint planar manipulator.

**Task 4.4 (5 points) Homogenous transformation:** Derive the homogenous transformation  $Rot_{\mathbf{k},\theta}$  (slide 129), which describes a rotation of  $\theta$  around an arbitrary vector  $\mathbf{k}$  ( $\mathbf{k} = k_x \vec{i} + k_y \vec{j} + k_z \vec{k}$ ).

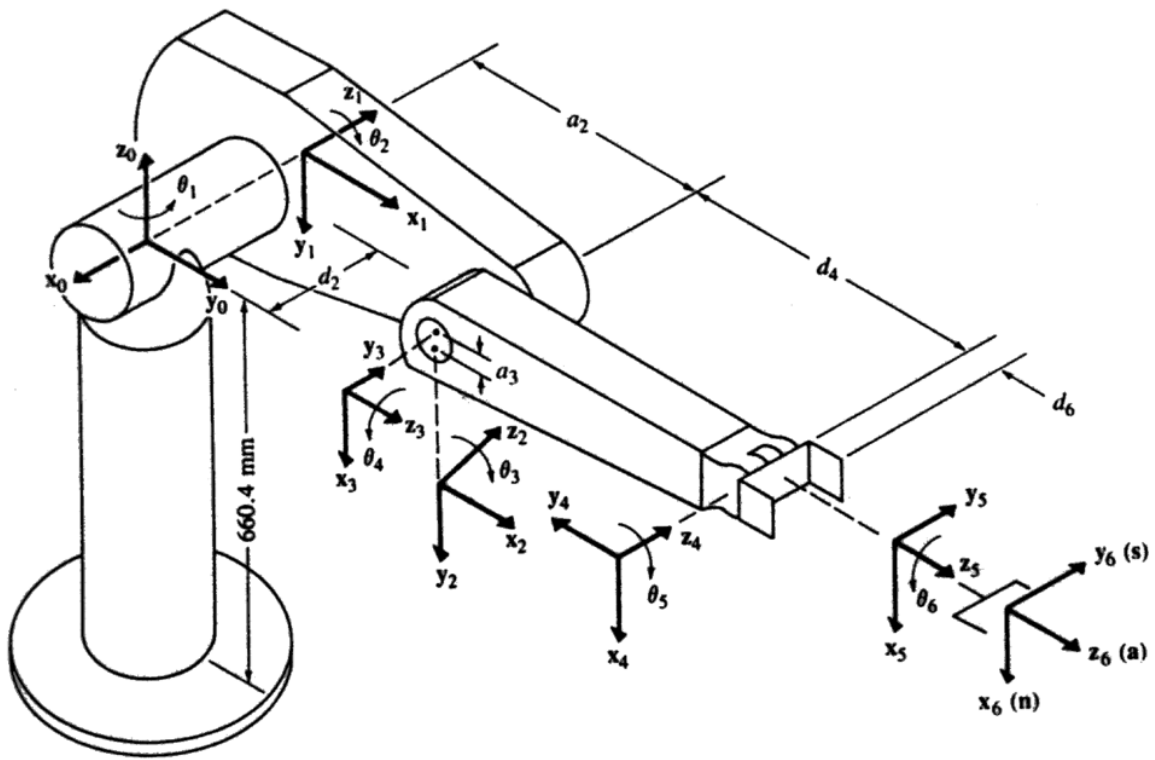


Figure 3: PUMA560 manipulator.