INF3480/INF4380 - Assignment 2

Eirik Kvalheim and Jørgen Nordmoen

Due: Wednesday, April 12th 2017

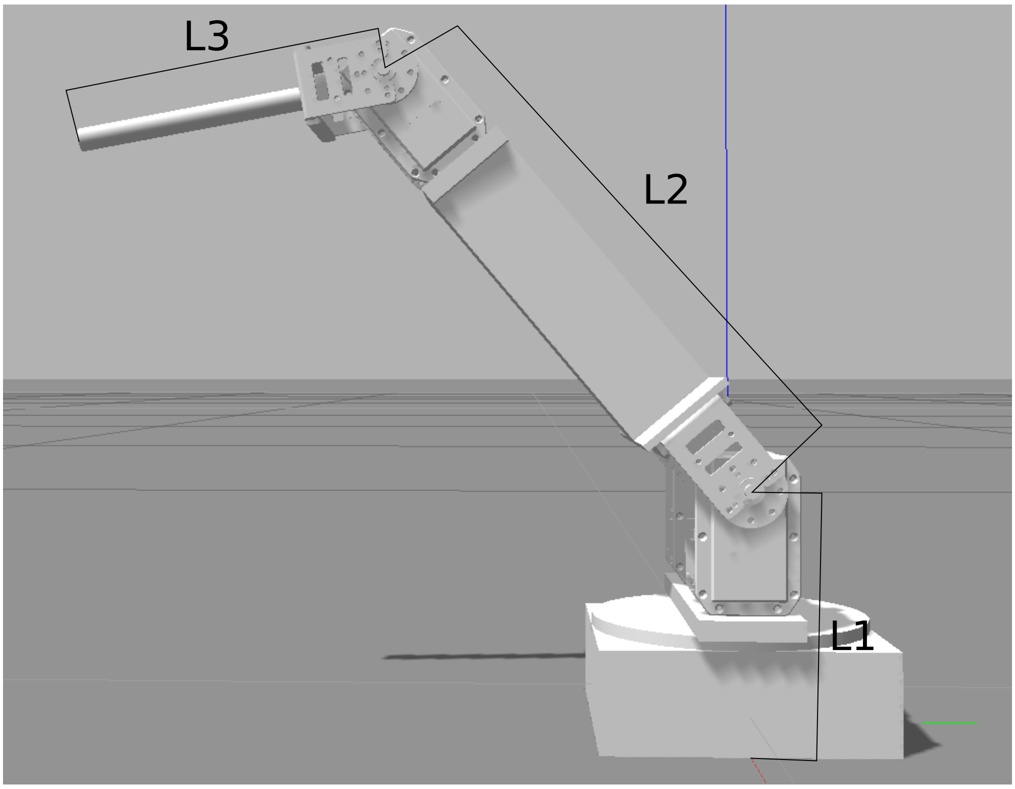

Figure 1: Simplified robot model in gazebo

Introduction

In this exercise we will keep working with the simplified CrustCrawler robot. The robot is displayed in figure 1. In this assignment you are free to choose your preferred programming language. Python will be a mandatory language in the next assignment. Dimensions; L1 = 100.9, L2 = 222,1, L3 = 136.2 in mm.

Task 1 - Forward and inverse kinematics

Implement the forward and inverse kinematics as functions.

a) The forward kinematics function takes 3 joint angles as input, and gives the corresponding cartesian coordinates for the tip of the arm as output. The function shall look like this:

function cart_cord = forward(joint_angles)

where both *cart_cord* and *joint_angles* are vectors of size 3.

b) The inverse kinematics function takes the cartesian position of the tip of the pen as input, and gives the corresponding joint configuration(s) as output. The function shall look like this:

function joint_angles = inverse(cart_cord)

where both *cart_cord* and *joint_angles* are vectors of size 3.

c) Use the functions to show how you can verify that the inverse and forward kinematics are correctly derived.

Task 2 - Jacobian I

Use the same coordinate assignments as you did when you followed the DH convention.

a) Derive the Jacobian matrix for the simplified CrustCrawler robot.

b) What do we call configurations for which rank J(q) is less than the maximum value?

c) Use the Jacobian matrix to find the singular configurations for the robot.

d) Give an evaluation of these results, and draw at least one of these singular configurations. The drawing(s) shall have a simple 3D layout like the ones in the lecture slides.

e) A natural extension of the simplified robot would be a spherical wrist on the end. How can a spherical wrist alone (only picturing the wrist) be in singularity? Draw and explain.

f) What is the practical consequenses of not handeling singularities?

g) If your robot for some reason gets into a singularity, how could you easily get it out (withouth cutting the power and moving it by hand)?
Assuming that your inverse function is not able to go to another point, because of the singularity. Here you can assume that you still have control over your robot, and are able to send new commands/run new functions.

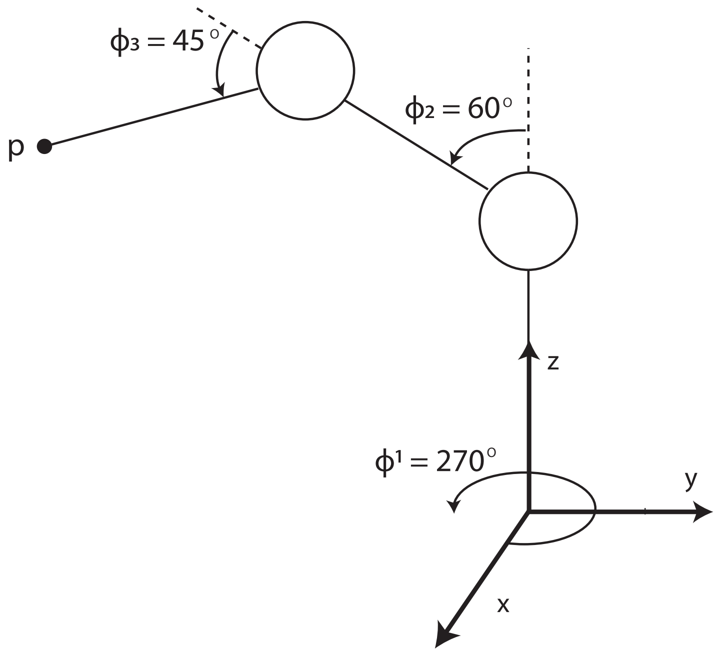

Figure 2: Robot configuration

Task 3 - Jacobian II

Use the same coordinate assignments as you did when you followed the DH convention.

a) Implement the Jacobian matrix as a function. It takes the instant joint angles and joint velocities as input, and gives a 3-dimensional vector of cartesian velocities of the tip of the pen as output.
The function shall look like this:

function cart_velocities = jacobian(joint_angles, joint_velocities)

where both *joint_angles*, *joint_velocities* and *cart_velocities* are vectors of size 3.

b) Point p is located at the end-effector of the robot (the tip of the last arm). We adjust the robot as displayed in figure 2, where $\phi_1 = 270°$, $\phi_2 = 60°$ and $\phi_3 = 45°$ (these angles are not to be used directly, you have to figure out the correct θ-angles corresponding to your placement of the joint coordinate frames, referred to when you derived your DH-parameters).

Given the configuration in figure 2 and the joint speed vector $\dot{q} = [\dot{\theta}_1, \dot{\theta}_2, \dot{\theta}_3]$, where $\dot{\theta}_1 = 0.1 rad/s$, $\dot{\theta}_2 = \dot{\theta}_3 = 0.05$ rad/s, use your function to calculate the cartesian velocity of point "p" relative to the base coordinate frame.

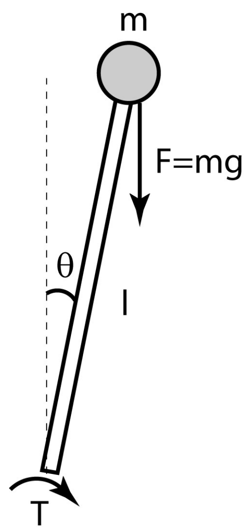

Figure 3: The inverted pendulum

Task 4 - Dynamics

In this exercise we will model joint 2 of the simplified robot as an inverted pendulum. The pendulum has a mass m which is located on the top of the pendulum, see figure 3. The distance from the rotation point to the mass is l. The moment of inertia I of the pendulum is ml^2. The motor in the joint provides a torque τ_m.

Find the ***Lagrangian*** $\mathcal{L}$, and derive the dynamics of the inverted pendulum using *Euler-Lagrange* formulation. Set zero potential energy to the rotation point.

Requirements:
Each student must hand in their own assignment, and you are required to have read the following declaration to student submissions at the department of informatics: http://www.ifi.uio.no/studinf/skjemaer/declaration.pdf

IMPORTANT: Name the pdf file: "inf3480-oblig2-*your_username.pdf*".
Submit your assignment at https://devilry.ifi.uio.no.

Your submission must include:

- A pdf-document with answers to the questions, and the illustrations asked for in Task 2.
- Your code and a description of how to run it.

Deadline: Wednesday, April 12th 2017 You can use the slack channel *assignment 2* for general questions about the assignment, and the channels *jacobian* and *dynamics* for discussion. Do not hesitate to contact us if you have any further questions.

Eirik Kvalheim - *eirikval@mail.uio.no*
Sadegh Hosseinpoor - *sadeghh@mail.uio.no*
Marius Wilhelm Olstad - *mariuwo@mail.uio.no*
Aryan Esfandiari - *aryane@mail.uio.no*