# IN3140 - Assignment 2

Due: Friday, March 11th, 23:59 pm

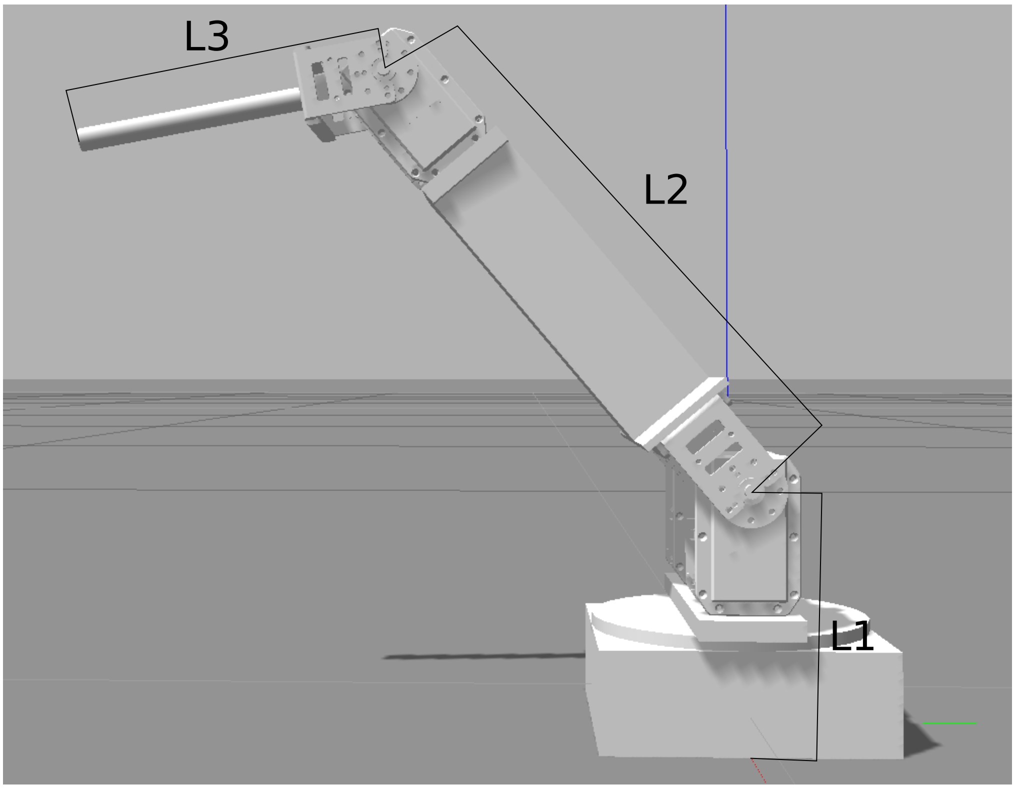


Figure 1: Simplified robot model in gazebo

## Introduction

In this exercise we will keep working with the simplified CrustCrawler robot. The robot is displayed in figure 1. The dimensions in mm are;

- L1 = 100.9
- L2 = 222.1
- L3 = 136.2

# Task 1 - Forward and inverse kinematics - (40%)

Implement the forward and inverse kinematics as functions in MATLAB or Python. Let *cart_cord* be a vector of size 3.

* *If you are using Python the libraries NumPy and SymPy could prove helpful.*

**a) 10%** The forward kinematics function takes x sets of joint angles as input, and gives the corresponding cartesian coordinates for the tip of the arm as output:

**function cart_cord = forward(joint_angles)**

**b) 10%** The inverse kinematics function takes the cartesian position of the tip of the pen as input, and gives the corresponding joint configurations as output:

**function joint_angles = inverse(cart_cord)**

**c) 10%** Use the functions to show how you can verify that the inverse and forward kinematics are correctly derived. Hint: Use a function like round() and at least 4 decimals accuracy.

**d) 10%** The TCP (Tool Center Point) is located at [x,y,z]=[0;-323.9033;176.6988] in the Base coordinate frame. Calculate the four sets of solutions of the joint variables according to your DH setup. The answers must be in degrees with max four decimals.

# Task 2 - Jacobian I - (40%)

Let the $Z_1$, $Z_2$, and $Z_3$ axis be parallel and pointing out of the paper in figure 2

**a) 10%** Derive the Jacobian matrix for the simplified CrustCrawler robot.

**b) 5%** What do we call configurations for which rank J(q) is less than the maximum value?

**c) 10%** Use the Jacobian matrix to find the singular configurations for the robot.

**d) 5%** 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, see referred standard below.

**e) 5%** 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. The drawing shall be a simple 3D illustration.
**Use the standard for symbolic representation of 3D robot joints, found in Chapter 1.1.1 in the course book. You can se an example of a correct 3D representation of robot joints on page 85 in the course book (2006), figure 3.7.**

**f) 5%** What is the practical consequenses of not handeling singularities?

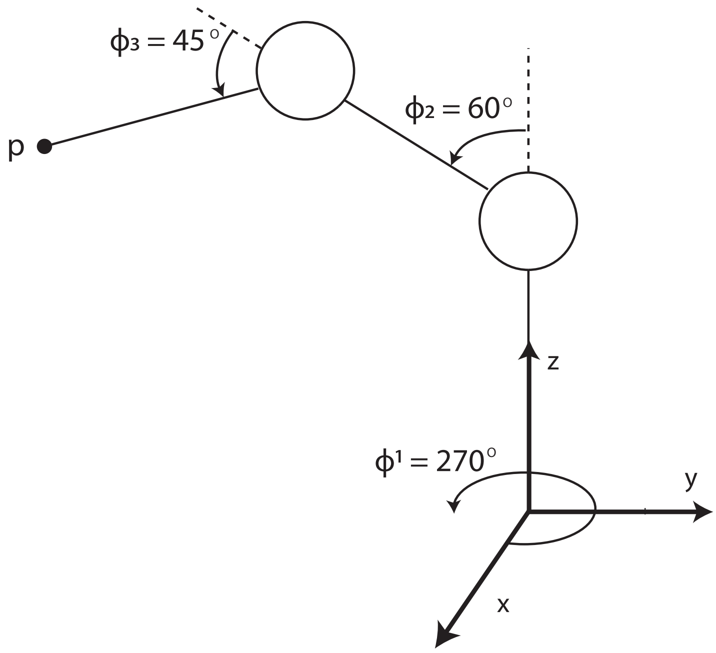


Figure 2: Robot configuration

## Task 3 - Jacobian II - (20%)

Let the $Z_1$, $Z_2$, and $Z_3$ axis be parallel and pointing out of the paper in figure 2

**a) 10%** Implement the Jacobian matrix as a function in MATLAB or Python. 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_velocities* and *cart_velocities* are vectors of size 3.

**b) 10%** 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 ($\phi$) angles are not to be used directly, you have to figure out the correct $\theta$-angles corresponding to the placement of the joint coordinate frames.

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.

**REQUIREMENTS:**
**Obtain a total score of at least 40 %**
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: https://www.uio.no/studier/eksamen/obligatoriske-aktiviteter/mn-ifi-obliger-retningslinjer.html

**IMPORTANT! Name the pdf file;**

**"IN3140_oblig2_*your_username.pdf*"**

Submit your assignment at https://devilry.ifi.uio.no/
Your submission must include:

1.) A pdf-document with answers to the questions.

2.) The two illustrations asked for in question 2d and 2e

3.) **A README.txt containing a short reflection on the assignment**; what was dificult, what was easy, was there anything you could have done better?

If you have used MATLAB, Python or other tools for computing an answer, your solution and approach must be illustrated and explained thoroughly in the pdf file. The files containing the code must also be delivered and named;

**"IN3140_oblig2_taskXX_*your_username.py .m*"**

You are free too use any programming language and tools you are familiar with, unless stated otherwise. However we strongly recommend doing task 2 by hand. In order to get a passed grade you will need to answer satisfactory on 40% of the assignment.

***Deadline: Friday, March 11th, 23:59 pm***

You can use the mattermost channel *IN3140* for general questions about the assignment and for discussion.

Do not hesitate to contact us if you have any further questions.

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